MEMOIRS OF THE GEOLOGICAL SURVEY.

SPECIAL REPORTS ON THE MINERAL RESOURCES OF GREAT BRITAIN.

VOL. XIII.—IRON ORES (*contd.*). PRE-CARBONIFEROUS AND CARBONIFEROUS BEDDED ORES OF ENGLAND AND WALES.

By SIR A. STRAHAN, K.B.E., Sc.D., LL.D., F.R.S.; W. GIBSON, D.Sc.; T. C. CANTRILL, B.Sc.; R. L. SHERLOCK, D.Sc., and HENRY DEWEY.

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232. ABERGAVENNY	1 6	1 6	2 0
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247. SWANSEA	1 6	1 6	2 6
248. PONTYPRIDD	1 6	1 6	3 6
249. NEWPORT (Mon.)	1 6	1 6	1 6
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261-2. BRIDGEND	1 6	1 6	1 6
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267. HUNGERFORD and NEWBURY	—	1 6	2 6
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311. WELLINGTON and CHARD	—	1 6	1 3
314. RINGWOOD	—	1 6	1 0
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PREFACE BY THE DIRECTOR.

This volume, forming the last of the series of 'Special Reports' on iron-ores deals with some sources which are practically inexhaustible, but which are being little drawn upon at the present day. The ores imbedded in the Lower Palæozoic rocks of N. Wales have not been fully exploited, and have so far proved disappointing. The highly disturbed character of the strata in which they occur, their general remoteness from the centres of the iron-industry, and more especially their liability to vary in quality, have been the chief reasons why many have been abandoned, after repeated trials. The ores imbedded in the Carboniferous strata were on the other hand, at one time the principal source of iron in this country. A description of them was commenced in 'The Iron Ores of Great Britain,' of which four parts appeared in the years 1856 to 1862. That publication originated in the presentation to the Museum of Practical Geology, by Mr. Blackwell of Dudley, of a series of British iron-ores mostly from the Coal Measures, which he had collected for the Exhibition of 1851. The presentation was accompanied by a contribution of £500 towards the cost of an analytical investigation of the more important specimens, and as a result of this generosity the memoir was put in hand. It gives short but instructive descriptions of the ores, and a series of analyses which are unsurpassed for precision, but it deals only with the Northern and Midland Counties, South Staffordshire, South Wales, Shropshire and North Staffordshire and leaves untouched some areas, including the Mesozoic districts from which a large proportion of our home-production of ore is now derived. Later memoirs contain descriptions of some of these areas, but not of all, and it was clearly desirable not only to bring together information that was scattered through several publications, but to produce a systematic account that should cover the whole country. To render this account complete it was necessary to include many Carboniferous ores which are now neglected, and the utilisation of which in the future appears at present to be little more than a remote possibility.

The field-work which was necessary was carried out in 1917, and the present volume is the joint work of the members of the staff who were engaged in that work. North Wales and Somerset were examined by Mr. Cantrill and Dr. Sherlock, and Northumberland and Durham by the latter. The account of North Staffordshire and Shropshire has been prepared by Mr. Dewey, that of the remaining areas by Dr. Gibson.

We have to acknowledge the cordial co-operation of the many owners and managers of mines and works to whom it was necessary to apply.

A. Strahan,
Director.

Geological Survey Office,
28, Jermyn Street,
London, S.W. 1,
18*th May*, 1919.

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BEDDED IRON ORES
PRE-CARBONIFEROUS AND CARBONIFEROUS.

CHAPTER I.

INTRODUCTION.

By Sir A. Strahan.

The term 'bedded ores,' as applied to the iron-ores of pre-Carboniferous and Carboniferous formations, is used to indicate beds rich in iron which form members of a stratigraphical sequence. The enrichment of such beds has been the result in some cases of subsequent alteration, in others has been contemporaneous with deposition, but in either case the ore-bodies behave as stratified deposits, as contrasted with the ores contained in flats, pipes, veins, etc.

The ores associated with the pre-Carboniferous formations are not abundant and have been little worked. With the exception of a few in rocks of Cambrian age, they belong to the Ordovician group, and are confined to Anglesey, Carnarvonshire and Merioneth. These ores usually show pisolitic structure and consist in part of magnetite and ferruginous sandstone. The content of metallic iron ranges up to 52·1 per cent., but averages about 45 per cent. Silica and sulphur are sometimes present in prohibitive quantities but the principal obstacles to profitable mining have lain in the faulted character of the deposits and their remoteness from the centres of the smelting industry. The output has never exceeded 80,000 tons a year, and for several years, as between 1860 and 1890, the Home Office statistics show no return. Since 1908 the output has lain between 10,000 and 14,000 tons a year.

The reserves of these ores are difficult to estimate, for they occur in rocks which are so folded and faulted that their range in depth and horizontal extent could only be ascertained by a more complete detailed survey than has as yet been possible. Another uncertain factor is introduced by the possible change of an ore profitable at outcrop into a hard siliceous and sulphury ore in depth, below the level of oxidation. Under such circumstances no precise estimate is possible. The ores, therefore, are included with others to which a similar remark applies, and an arbitrary aggregate figure is given which bears some relation to the productiveness in past years, but does not profess to represent the quantity of ore likely to exist.

The Carboniferous ores, though for the most part neglected now in favour of hæmatites and Mesozoic ores, furnished the bulk of the raw material used in this country till the middle of the last century, and in fact determined the location of the iron-industry. They occur as bands or nodules of clay-ironstone (argillaceous carbonate), or as blackbands (beds of carbonaceous ore) in the

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Coal Measures, and, in the north-east of England, also in the Millstone Grit and Carboniferous Limestone Series. Their vast abundance and accessibility in the Middle Coal Measures of some coalfields led to their being mined or quarried in very early times, and, until smelting by coal was adopted, primarily through the growing scarcity of charcoal, the coals associated with them were regarded in some of the coalfields as of secondary importance. At the present day they are rarely worked except in association with coal.

In composition, except for the high percentage of carbonaceous matter in the blackbands of North Staffordshire, they resemble the Mesozoic ores, but as a whole they are more uniform and contain less moisture. Metallic iron ranges from 16 to 38 per cent. with an average of 29 per cent. for the raw stone. They are at present used in the manufacture of special types of iron, commanding a high price and of world-wide reputation; but it is not clear to what extent the iron owes its superiority to the character of the ores and how much to methods of manufacture. The displacement of Carboniferous by Mesozoic ores appears to have been determined chiefly by the comparative cost of working.

In 1913 the output of the Coal Measure ironstones amounted to 941,128 tons, of which 859,244 tons was raised in North Staffordshire. This is a considerable falling off from that of 1856 when the output amounted to 3,743,200 tons, and when no less than 2,205,000 tons was mined in South Staffordshire.

The reserves of all British iron-ores were discussed in detail in the 'Summary of Progress for 1917,' *Mem. Geol. Survey*, 1918, pp. 5–28.

That the reserves of Carboniferous bedded ores are great admits of no doubt, but attempts to estimate them with precision would be generally futile. The amount worked out could only be determined within wide limits, and the value of the part left could only be ascertained by trial. That the value of the ore and yield per acre which have been recorded for the areas worked, would hold good for the reserve areas, would be an unsafe assumption.

In the following table the figures for "Additional Reserves" apply only to areas in which the ironstones are known to have a fairly constant development.

Reserves (raw stone) of the Carboniferous Bedded Ores in England and Wales.

	Areas partially developed. Tons.	Additional reserves. Tons.
Redesdale and district ...	1,500,000	—
Yorkshire	110,760,000	104,320,000
Derby—Notts	566,560,000	13,440,000
Warwickshire	4,608,000	—
Staffordshire, North ...	364,417,000	939,883,000
Staffordshire, South ...	11,520,000	62,680,000
Shropshire	—	30,000,000
Flintshire, Denbighshire ...	—	20,000,000
S. Wales and Monmouthshire	Upwards of	5,000,000,000
Total	1,059,365,000	6,170,323,000
Total	7,229,688,000 tons.	

Considerable as these quantities are they fall far short of previous estimates, such as that given in ' The Iron Resources of the World.' Moreover, under present conditions only about half of the amount estimated under the head ' Areas partially developed ' would be available, and considerably less than half of that estimated under ' Additional Reserves.' In both cases under existing circumstances constancy of supply would be contingent upon the possibility of working coal and ironstone in association.

CHAPTER II.

PRE-CARBONIFEROUS BEDDED ORES.

By T. C. Cantrill and R. L. Sherlock.

INTRODUCTION.

In England and Wales bedded iron-ores of Pre-Carboniferous age are known only in Anglesey, Carnarvonshire and Merioneth. Their existence was recognised at least as early as 1838, for the original Ordnance Maps published about that time show an 'ironstone-quarry' at Bettws Garmon (Carnarvonshire), and also a place called 'Tyllau-mŵn' ('the mine-shafts' or 'ore-pits') near Drwsynant (Merioneth), at both of which localities iron-ore has been worked on the crop at various periods.

Other occurrences were recorded on the Geological Survey maps published between 1850 and 1855, the places in question being three in Anglesey; four localities near Tremadoc, with Trwyn-y-tâl and Llanengan, all in Carnarvonshire; and Cross Foxes and Ffordd-ddu in Merioneth.

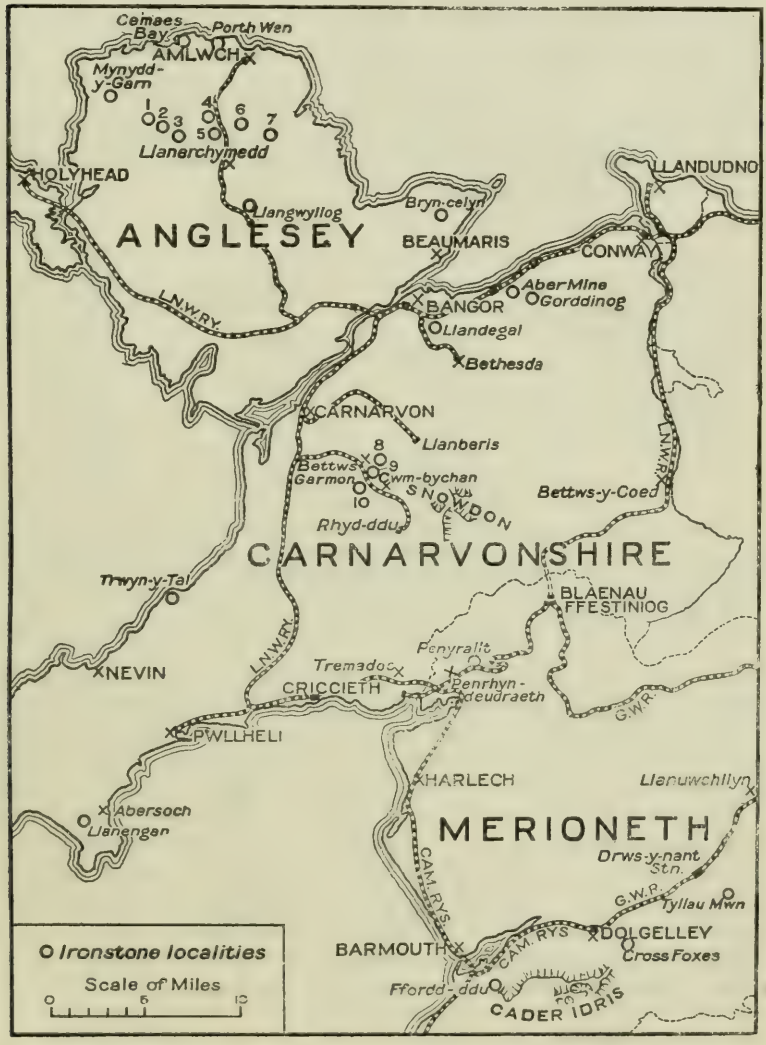
In 1846 the occurrence of "very rich ironstone" between Tremadoc and Portmadoc was recorded by Daniel Sharpe[1], who remarked that the ore occurs in beds 4 in. thick alternating with ferruginous grit. In the same year Sedgwick[2] mentioned that "large masses of pisolitic iron ore" associated with loadstone [magnetite] were at that time "extensively worked" near Tremadoc. He noted that some of the masses are injured by much-disseminated iron-pyrites, as is the similar ore on the coast north of the Rivals [Yr Eifl], *i.e.*, at Trwyn-y-tâl. He referred also to the pisolitic ore near St. Tudwal's Head, presumably at Llanengan, and to its occurrence west of Abererch. In 1852, in another paper[3], he again speaks of "beds or large concretionary masses of magnetic and pisolitic iron ore" in the country east [?west] of St. Tudwal's Road; between Clynnog and the Rivals [Yr Eifl], *i.e.*, at Trwyn-y-tâl; on the eastern side of the Merioneth anticline, and on the north-western flank of Cader Idris.

In 1854 Prof. Samuel Haughton[4] published a description and analyses of the iron-ores of Gareg-fawr (Bettws Garmon) Trwyn-y-tâl (Llanaelhaiarn) and Llanengan (near Abersôch). He remarked that the Gareg-fawr ore is dark green in colour, oolitic in texture, and magnetic; and that the iron occurs in the form of protoxide and peroxide, some amount of these being combined as the magnetic oxide, and some existing as the carbonate. He regarded the ore as a bedded deposit conformable to the associated

[1] *Quart. Journ. Geol. Soc.*, vol. ii, 1846, p. 283; *vide* p. 302.
[2] *Ibid.*, vol. iii, 1847, p. 133; *vide* pp. 140–142, 149.
[3] *Ibid.*, vol. viii, 1852, p. 136; *vide* p. 148.
[4] 'On the Iron Ores of Carnarvonshire,' *Journ. Geol. Soc. Dublin*, vol. vi, pt. 1, 1853–4, pp. 128–133.

slates, and assigned it to the "lower portion of the lingula beds." An analysis quoted by Haughton will be found later (p. 24).

FIG. 1.—*Map showing Ironstone localities in the Pre-Carboniferous rocks of North Wales.*



1. Ucheldref-uchaf.
2. Fferam-uchaf.
3. Llanbabo, lane S.S.W. of.
4. Penbol.
5. Gwredog.
6. Pwll-côch-isaf.
7. Llandyfrydog Mill.
8. Gareg-fawr.
9. Ystrad.
10. Tyddyn-bâch.

Of the Trwyn-y-tâl ore Haughton's is the only published account that we have found, except that Ramsay states the ore to have been worked about 1867. Haughton described it as a bed of pisolitic magnetic ore, coarser grained than that of Gareg-

fawr, redder in colour, more variable in composition, and highly phosphoric. The bed in which the ore occurs is 18 ft. thick, is conformable to the associated black slates, strikes E. 35° N., and dips " 80° N." The average composition of this ore is given in column I of the table below.

Near the walls of the bed of pisolitic ore described above, some black slaty ore (analysis II, below) occurs, containing 40·34 per cent. of mixed peroxide and protoxide. Large nodules of a fine oolitic texture and reddish colour occur also, which he describes as kidney-ore. This contains a much larger proportion of protoxide than usual, and appears to be a nodular spathic ore with a considerable quantity of phosphoric acid. Its composition is shown in column III below.

The following analyses are given by Haughton:—

	I.		II.		III.
Loss on ignition ...	18·61	...	8·13	...	28·03
Clay and silica ...	13·00	...	38·79	...	2·62
Peroxide of iron ...	25·29	}	40·34	{	5·92
Protoxide of iron...	33·24	}		{	49·92
Alumina	7·09	...	12·55	...	3·12
Lime	1·85	...	Trace	...	5·87
Magnesia	—	...	0·31	...	Trace
Phosphoric acid ...	1·32	...	0·07	...	4·45
		...		...	
	100·40	...	100·19	...	99·93

I. Pisolitic magnetic iron-ore. Average composition, deduced from trials on seven specimens. The 7·09 of alumina contains some phosphoric acid. Metallic iron in raw ore, 43·55 per cent.; in roasted ore, 53·50.

II. Black slaty iron-ore.

III. Kidney iron-ore. Metallic iron in raw ore, 42·95; in roasted ore, 59·66.

The beds of pisolitic ore of Llanengan are described by Haughton as comformable to the associated black slates, though affected by the disturbances to which the latter have been subjected. The ore-beds in Homfray's mine have an average thickness of 25 ft.; in Holland's quarry at Vron their thickness is 18 ft.

Haughton pointed out that the large percentage of phosphorus in the Carnarvonshire ores he described was detrimental to their market-value, and concluded that the ores are not lodes, but bedded deposits "formed by chemical action at the time of deposition of the slates in which they are found."

The following average composition of the black oolitic variety of the Llanengan ore is based on three analyses:—

	Per cent.
Loss by ignition	18·99
Clay and silica	22·61
Peroxide of iron	4·04
Protoxide of iron	44·01
Alumina	5·74
Lime	1·57
Magnesia	1·21
Phosphoric acid	1·86
	100·03
Metallic iron in raw ore	37·06
Metallic iron in roasted ore	45·75

Ramsay[1] recorded the occurrence of these ores at the following localities:—

Anglesey:—Bryn-poeth (near Llangoed) and Llanfihangel, 3 miles N. of Beaumaris.

Carnarvonshire:—Bettws Garmon, 6 miles S.E. of Carnarvon; Trwyn-y-tâl, Llanaelhaiarn, on the coast north of Yr Eifl and 6 miles N.E. of Nevin; Llanengan, 7 miles S.W. of Pwllheli; and Tremadoc.

Merioneth:—Ffordd-ddu, Geugraig, Pen-y-bwlch-gôch, and Cross Foxes, near Cader Idris, 3 miles S.W. of Dolgelley.

He considered that the ore was a bedded deposit and that its horizon was a constant one at the top of the 'Arenig' Series.

In 1889 Prof. G. A. J. Cole and A. V. Jennings in a paper[2] on the Cader Idris region referred to the pisolitic ironstone of the Llyn-Aran district (2½ miles S. by E. of Dolgelley). It is stated to contain clayey concretions an inch or so in length, and a large quantity of disseminated pyrrhotite (magnetic pyrites, Fe_6S_7). This mineral forms in places concentrically-built ovoid concretions. A specimen of ore from nearer the Cross Foxes Inn would be better described, according to the authors, as an oolite than a pisolite, as the grains are barely 1 mm. in diameter. The iron in this rock is stated to be mainly magnetite, and the ore phosphoric.

In 1899 Dr. C. A. Matley[3] referred to the iron-ore as occurring at Pen-terfyn and Porth-Padrig, near Cemaes in Anglesey, and in a later paper[4] included a notice of that at Porthwen Bay near Amlwch, in the same county. He subsequently recorded[5] its occurrence at Gorlan-gôch near Mynydd-y-Garn. The same author[6] noted the occurrence at Llanfaelrhys, near Aberdaron, in Carnarvonshire, of massive beds of ironstone, altogether different in character from the pisolitic ore, and of a different geological horizon, *i.e.*, of the zone of *Didymograptus hirundo* (Arenig) or of *D. bifidus* (Llanvirn).

In 1910 Prof. W. G. Fearnsides[7], in a paper on south-east Carnarvonshire, gave some valuable details of the pisolitic ore of Tremadoc. He showed that it occurs in the zone of *Nemagraptus gracilis*, or in the overlying sub-zone of *Climacograptus peltifer*, in association with shales of Glenkiln age, and that it is therefore of Ordovician age, and not Cambrian as had previously been supposed. At the same time he recorded the occurrence of ironstones of a different character (concretionary iron carbonate,

---

[1] 'The Geology of North Wales,' *Mem. Geol. Surv.*, ed. 1, 1866, pp. 171, 252; ed. 2, 1881, pp. 38, 40, 91, 206–7, 213–14, 223, 250.

[2] *Quart. Journ. Geol. Soc.*, vol. xlv, 1889, p. 422; *vide* pp. 426–7, 436–7.

[3] *Ibid.*, vol. lv, 1899, p. 635; *vide* pp. 672, 673.

[4] *Ibid.*, vol. lvi, 1900, p. 233.

[5] *Ibid.*, vol. lvii, 1901, p. 20.

[6] *Geol. Mag.*, 1902, p. 118.

[7] *Quart. Journ. Geol. Soc.*, vol. lxvi, 1910, p. 142; *vide* pp. 170–173, 185, 186.

occasionally showing cone-in-cone structure) in the Lingula Flags and Tremadoc Series of the Cambrian System of the same district. It appears that it was in digging for coal in the black shales with which the pisolitic ore is associated that the ironstone itself was discovered. The ore occurs in the form of lenticular masses, which vary in size from that of "a bean to that of a 100-ton schooner." Until 1860 the ore was worked with great zeal; but as in the deeper workings the proportion of sulphur increased, it became unprofitable. The industry has long been extinct. The old workings or trial-holes near Tremadoc are situated at the Tyddyn-dicwm mine, about $1\frac{1}{3}$ miles to the west-north-west; at the Tremadoc mine, 500 yards west; at Pen-syflog, half-a-mile south, and to the south of Pen-amser, three-quarters of a mile south-west of Tremadoc; also near Ynys-galch, on the northern outskirts of Portmadoc. The ore was found to extend along a crush-belt accompanying the Penmorfa Fault, an overthrust that crosses the district in a direction ranging N. 50° W. from Portmadoc past Penmorfa. The ore was extracted, chiefly by means of open quarries, at intervals along the north-eastern side of the fault for a distance of two miles. The general dip of the country-rock is N.N.E. at 20° or 30°.

In 1915 Mr. T. C. Nicholas[1] in a paper on the St. Tudwal's Peninsula, Carnarvonshire, has referred to the lenticular masses of pisolitic iron-ore of that district. They occur in association with graptolitic shales (the Hendy-Capel Mudstones) referable to the zone of *Nemagraptus gracilis*. Mr. Nicholas gave a figure of the ironstone-quarry near Hendy-Capel, where some of the beds are 15 ft. thick. The ore has been quarried (presumably for iron-ore) at intervals from Pen-y-gaer ($\frac{3}{4}$ mile N.N.E. of Llanengan Church) to Llanengan Rectory. Thence the ore-belt runs east-south-eastwards by Hendy-Capel to Deugôch, a total distance of $1\frac{1}{4}$ miles. It is closely associated with a powerful overthrust fault, as at Tremadoc. A small patch of ore occurs farther south, near Ty-newydd. There appears to be some development of similar ore in the Llanengan Mudstones (Arenig Series) also, at Pen-y-gwaith and Hendy, south of Porth-fawr.

The ironstone was worked by openworks and day-levels. From the Hendy-Capel quarry a light tramway was constructed for a distance of $1\frac{3}{4}$ miles to the southern headland of Porth-fawr, where the ore was shipped from a small jetty, the site of which is occupied by the lifeboat-house and slip-way. The ore is believed to have been sent to Swansea for smelting, but the industry seems to have been dormant for 50 years.

In Anglesey, according to Mr. Greenly, pisolitic iron-ore has been found at 15 localities.

In the following table an asterisk marks the palæontological zones and geological horizons to which the pisolitic ores of North Wales have been assigned by various authors:—

[1] *Quart. Journ. Geol. Soc.*, vol. lxxi, 1915, p. 83; *vide* pp. 113–116, 122–126.

System.	Series.		Palæontological Zones.
Ordovician	Bala.	Hartfell.	*Several.
		Glenkiln.	*Zone of *Climacograptus peltifer.* * ,, *Nemagraptus gracilis.*
	Llandilo.		* ,, *Glyptograptus teretiusculus.*
	Llanvirn.		* ,, *Didymograptus murchisoni.* ,, *Didymograptus bifidus.*
	Arenig.		,, *Didymograptus hirundo.* * ,, *Didymograptus extensus.*
Cambrian	Tremadoc.		Shumardia and Dictyonema Beds.
	Lingula Flags.		*Olenus and Lingulella Beds.

The majority of the ores appear to occur in or near the zone of *Nemagraptus gracilis*. Mr. Greenly states that in Anglesey the ore occurs at two closely approximate horizons, the upper one in the zone of *Nemagraptus gracilis*, the lower and more frequently occurring one in the zone of *Glyptograptus teretiusculus*. Mr. T. C. Nicholas thinks that in St. Tudwal's Peninsula there are two more widely separated horizons of pisolitic ores. At Hendy-Capel[1] a specimen of *Nemagraptus gracilis* was found in the ore, which may therefore be presumed to be of the age of that zone-fossil, as in Anglesey. On the other hand, similar ore occurs south of Porth-fawr[2] apparently interbedded in the Llanengan Mudstones, which are of Arenig age (*Didymograptus extensus* Zone).

Prof. Fearnsides[3] finds that the Tremadoc ironstone accompanies rocks containing Glenkiln graptolites.

The occurrences of ore at Cross Foxes, near Dolgelley, and at Ffordd-ddu, near Arthog, are regarded by Dr. A. H. Cox, who has surveyed the Cader Idris district, as belonging to the Dicranograptus Shales (Llandilo-Bala), and probably to the lower part. They are therefore of approximately the same age as those mentioned above.

As for the other occurrences, the ironstone of Trwyn-y-tâl and of Bettws Garmon are, according to Ramsay,[4] of the same age as that at Tremadoc, *i.e.*, Glenkiln. Prof. Fearnsides,[5] however,

[1] *Quart. Journ. Geol. Soc.*, vol. lxxi, 1915, p. 124.
[2] *Loc. cit.*
[3] *Rep. Brit. Assoc.* for 1907 (1908), p. 510.
[4] 'Geology of North Wales,' *Mem. Geol. Surv.*, ed. 2, 1881, p. 214.
[5] *Op. cit.*, p. 511.

states that, at Bettws Garmon, beds with *Lingulella* overlie the black shales with ironstones, which therefore belong to the Lower Lingula Flags (Cambrian), as had been stated by Haughton in 1854. He thinks that the horizon of the Trwyn-y-tâl deposit is higher than any of the others, and may belong to the Hartfell Series.

As to the origin of the ores there has been some difference of opinion. Prof. Fearnsides[1] considers that they are not bedded deposits, but were formed at the limit of a metamorphic aureole, in the first instance as spherules of iron sulphide (either pyrites or marcasite), which were later oxidized to fibrous limonite and compact magnetite. The ironstones are greatly disturbed by thrusts, faults, and foldings, and he considers that they are not definite beds, but exist as lenticular bodies produced by thrusting, and arranged in a linear manner that gives a false appearance of bedding.

The general consensus of opinion, however, has been in favour of their being truly bedded deposits. Mr. Nicholas[2] points out that in the St. Tudwal's Peninsula there are no igneous masses to produce the alleged metamorphic action, and that the lenticular structure is readily accounted for by the effect of intense earth-movements on a very hard and massive bed lying between softer strata. The presence of detrital quartz-grains, and occasionally of fossils, in the ore are additional points in his argument.

A resemblance between widely separated occurrences of the ore is worthy of mention in this connection. Ramsay[3] records that at Trwyn-y-tâl the ore is "said to lie in two bands, a red one and a black one." We find that this is also the case at Llandegai, near Bangor, where there is nine inches of alternating shale and black ore between red ore above and black ore below.

On the whole we think we are justified, in the present admittedly imperfect state of our knowledge, in regarding the ores as in all cases truly stratified.

We turn now to the structure of the ores.

Mr. Nicholas[4] states that the ironstone in St. Tudwal's Peninsula varies from a massive black rock built up almost entirely of pisolitic or oolitic grains, to a black mudstone in which these grains are distributed sparingly or aggregated into small nodules. The ore often contains streaks and lenticles of black mudstone, which differs from the more argillaceous portions of the ore only in the absence of pisolitic grains—in fact, the two types appear to shade one into the other, and sometimes contain fossils. Black siliceous nodules, measuring as much as an inch or more in diameter, are not uncommon. A fairly distinct boundary can generally be drawn between the thoroughly pisolitic and the more argillaceous portions of the ore, but, notwithstanding this, they appear to be intimately related: there is no discontinuity at the junction, and hand-specimens can be obtained in which pisolitic ore and black mudstone with detached siculæ of graptolites and horny brachiopods seem to be inseparably

[1] *Rep. Brit. Assoc.* for 1907 (1908), p. 510.
[2] *Op. cit.*, p. 125.
[3] *Op. cit.*, p. 214.
[4] *Op. cit.*, pp. 123, 124.

welded together. One such specimen from Hendy-Capel even shows a small portion of *Nemagraptus gracilis* in the mudstone. A noticeable feature in much of the iron-ore is that, while the shales and mudstones above and below are intensely crushed and slickensided, the ore itself is very little affected. Occasional planes of slickensiding run through it, and in the immediate neighbourhood of these and of the upper and lower surfaces of the mass the pisolitic grains are deformed and glazed by friction; but the bulk of the bed is totally undisturbed. This is, however, by no means always the case, for the more argillaceous portions of the ore sometimes show evidence that they must have undergone a great deal of shearing, and occasionally the ore exhibits a rude cleavage.

Prof. Fearnsides[1] has examined the pisolitic ores microscopically and finds that there is always much crushed streaky or fibrous shale between the pisolitic grains. Where freshest the grains show a radial arrangement of the constituent fibres; but there may also be a concentric structure, masked by the opacity of the mineral. Mr. Nicholas[2] states that in a sample from Hendy-Capel (St. Tudwal's Peninsula) the grains exhibit a well-marked concentric structure. They appear to be composed of minute flakes of a very slightly pleochroic pale-green mineral, giving very low colours between crossed nicols, set in a matrix of silica. The flakes are arranged in a tangential manner and many of the grains are formed round fragments of quartz. The matrix is composed chiefly of granular carbonate of iron, highly charged with a black opaque dust, probably magnetite; but there are a number of scattered quartz-grains.

From the prevalent small size of the grains, all these ores would be better described as oolitic rather than pisolitic.

As to the earliest output we have little information. The Tremadoc ironstones were being worked in 1846. The Mining Record Office statistics show that, in 1855, Carnarvonshire and Flintshire yielded between them 1,320 tons of ironstone, most of which was probably from the Coal Measures and hæmatite of Flintshire, and from that year onward we have statistics showing the annual output of iron ore in North Wales. Below is given in tabular form the total output,[3] so far as can be ascertained, of the pisolitic ores, the outputs of individual mines and quarries being given wherever possible. In the early records we cannot, unfortunately, always separate the statistics of different counties or of different ores, nor are the latter always correctly designated. The outputs of hæmatite for Flintshire are, for example, in some cases combined with the outputs of ore from Carnarvonshire, which were probably the bedded ores we are discussing.

All the workings have been at a shallow depth, either as open quarries or short drifts. Apart from the expense of deep mining there is the additional advantage in shallow work that the ore is improved by weathering, both by the loss of impurities and by the softening of the harder ore.

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[1] *Rep. Brit. Assoc.* for 1907 (1908), p. 511.

[2] *Op. cit.*, p. 124.

[3] Based on Mineral Statistics (*Mem. Geol. Surv.*), annually, 1855 to 1881, afterwards Mines and Quarries: Home Office Parliamentary Paper, annually.

Analyses are scarce. From such as we have been able to obtain, it appears that the percentage of metallic iron varies from 18·89 to 52·1, the average of 17 analyses being 35 per cent. The silica varies from 13·7 to 41·8, the average of 11 analyses being 24·4 per cent. Phosphorus ranges from ·353 to 4·961 per cent., giving an average percentage of 1·216, based on 11 analyses. Sulphur averages about ·42 per cent. Some of the Anglesey pisolites are little better than ferruginous sandstones, while a bulk analysis of the Drwsynant ore, perhaps the best ore in Merioneth, gave 44·8 per cent. of metallic iron. The Llandegai and Ystrad ores as sold average 38 per cent. of iron, silica 17 to 20, sulphur 1, phosphorus 1 to 1·5.

A serious objection to the use of these ores is their variable composition and their siliceous, sulphurous, and in some cases their phosphoric character. The Llanengan pisolitic grains have cores of iron sulphide—a serious handicap. In some cases the pyrites is finely divided and cannot be removed by hand-dressing. In most instances it is probable that the percentage of pyrites will be found to increase below the zone of weathering. Some analyses will be found under the descriptions of the mines.

Transport is often a difficulty. In some cases the mines or quarries are not far from a railway. Bettws Garmon, Llandegai, and Aber are well situated in this respect, but in many cases, such as Drwsynant and most of the Anglesey occurrences, the transport offers a serious obstacle to the economical working of the ores. The nearest furnaces for smelting them are at Mostyn in Flintshire and Brymbo in Denbighshire, or (by sea) Swansea in South Wales.

Year.	Output.	Remarks.
1855	1,320	Carnarvonshire and Flintshire hæmatite. May include pisolite.
1856	2,550	,, ,, ,,
1857	80,000	Carnarvonshire 'hæmatite'. Probably pisolite.
1858	3,590	Carnarvonshire 'brown hæmatite.' Probably pisolite.
,,	35,000	Sundry mines in N. Wales. May include pisolite.
1859	3,500	Carnarvonshire brown hæmatite. Probably pisolite.
,,	39,000	Sundry mines in N. Wales. May include pisolite.
1860	97	Carnarvonshire, Bettws Garmon, 'brown hæmatite,' probably pisolite.
1900	320	Gareg-fawr ... ... Iron 45 per cent.
1901	200	,, ... ,, 46 ,,
1902	6,800	,, ... ,, 43 ,,
1908	12,832	Gareg-fawr ... ... Iron 41·34 per cent.
,,	2,619	Bryn-castell (= Cross Foxes) ... Iron 38 ,,
1909	18,846	Gareg-fawr ... ... ,, 40 ,,
,,	8,023	Bryn-castell ... ... ,, 36 ,,
1910	13,200	Gareg-fawr ... ... ,, 40 ,,
,,	1,665	Bryn-castell ... ... ,, 36 ,,
1911	13,500	Gareg-fawr ... ... ,, 40 ,,
,,	298	Ystrad ... ... ,, 40 ,,
1912	12,900	Gareg-fawr ... ... ,, 40 ,,
,,	180	Ystrad ... ... ,, 40 ,,
,,	500	Bwlch-gôch near Dolgelley ... ,, 39 ,,
1913	9,300	Gareg-fawr ... ... ,, 40 ,,
,,	391	Bwlch-gôch ... ... ,, 39 ,,
,,	48	Llandegai and Ystrad ... ... ,, 39 ,,
1914	11,346	Carnarvonshire. Probably all pisolite ... ... ,, 40 ,,
1915	23,318	,, ,, ,, 40 ,,

CHAPTER III.

PRE-CARBONIFEROUS BEDDED ORES (*contd.*).

By T. C. Cantrill and R. L. Sherlock.

DETAILS OF THE MINES AND OCCURRENCES.

The geological structure of Anglesey[1] being highly complex, little is yet known about the range, either vertically or horizontally, of the pisolitic iron-ores. These crop out at a number of different localities, but how far any outcrop may be expected to extend at the surface, and to what depth it may be possible to follow the bed underground, are questions that are still unsettled. It is thus quite impossible to estimate reserves. The pisolites differ greatly in their characters. Some are ferruginous grits, and have little or no value as ores, and none of them seems ever to have been exploited beyond the trial stage. The following details of the quarries at Bryn-celyn and Bonw will serve as examples of the mode of occurrence of these Anglesey ores.

Anglesey.

Bryn-celyn or *Bryn-poeth Quarry near Llangoed* (disused).

A disused quarry, 250 yards north-east of Bryn-poeth Farm, near Bryn-celyn, $2\frac{1}{2}$ miles north of Beaumaris. The quarry is indicated on the Old Series Geological map by a dip-arrow, and is shown on the six-inch map.

Maps: One-inch New Ser. Ordnance and Geological 94[1]; Old Ser. Geological 78 N.E.; six-inch, Anglesey 15 N.W.

Latitude, 53° 17′ 40″. Longitude, 4° 5′ 52″.

The quarry is in either the Llanvirn or the Glenkiln group. It showed the following descending section in August, 1917:—

		Ft.	In.
5.	Shale, dark greenish-grey, with traces of graptolites and with small black nodules of ironstone here and there in the lower layers; passing down into 4	4	0
4.	Shales and bands of ironstone alternating (the shales in bands about $1\frac{1}{2}$ in. thick; the ironstone-bands about 3 in. thick); passing down into 3	1	0
3.	Massive ferruginous beds with shale partings; ooliths come in towards the base; passing down into 2 ...	4	6
2.	Oolitic ironstone	4	0
	The same ?, not well exposed	3	0
1.	Shales and hard siliceous rock, with some oolitic grains; in bottom of quarry	—	

The only well-marked lithological distinction is that between the uppermost shales (5) and the underlying ferruginous beds. The ironstones in 5 and 4 are concretionary nodules like those in the Coal Measures, and do not resemble the oolitic ironstone in

[1] See the New Series Geological Map, by E. Greenly.

the lower beds. The oolitic ironstone is presumably not more than 7 ft. thick; and as its upper limit is indefinite, and the extent to which the ooliths are present varies horizontally, perhaps not so much as that would be worth working.

The dip varies slightly, but is approximately W. 30° N. at about 16°.

The following analyses of two varieties of oolitic ore from this quarry were furnished by Messrs E. J. Morris and W. E. Williams, B.Sc., to Mr. Greenly, to whom we are indebted for a copy:—

	Var. A.		Var. B.
SiO_2	26·20	...	32·00
TiO_2	0·10	...	—
Al_2O_3	15·71	...	15·12
Fe_2O_3	3·70	...	—
FeO	28·45	...	35·35
FeS_2	1·39	...	0·15
MnO	1·67	...	trace
CaO	6·50	...	2·60
MgO	1·36	...	4·25
H_2O (hygroscopic)	7·90	...	9·20
H_2O (combined)		...	
CO_2	3·00	...	
P_2O_5...	3·93	...	1·53
	99·91	...	100·20
Iron (metallic)...	25·366	...	27·564

The analysis of Var. A is by Mr. Herbert Greenwood, 38, Liverpool Chambers, Liverpool; that of Var. B is by Messrs. Pattinson and Stead, 11, Queen Terrace, Middlesbrough.

The ore-bed is limited by its outcrop towards E. 30° S. The crop presumably runs N. 30° E. and S. 30° W., but how far is uncertain. There should be reserves under cover in the direction of dip (W. 30° N.); but an eastward dip in a brook 600 yards west of the quarry, shown on the geological map, suggests that the ore-bed rises again westward of the quarry.

There is at present only about 4 ft. of shale overburden (No. 5 of the section given above), but under the flat ground to the dip this might rapidly increase. Another difficulty would probably arise from deterioration of the ore laterally and vertically, and on the whole it is improbable that the bed could be profitably exploited.

The quarry was reopened about 1911-12, but abandoned, it is said, because the ore was found to be too siliceous.

The nearest railway stations are Pentraeth (L. & N. W.), nine miles west by cross-country roads, and Llanfairpwllgwyngyll (L. & N. W.), the same distance south-west by a direct road. The quarry is easily accessible from Beaumaris, $2\frac{1}{2}$ miles south.

Bonw, Mynydd-y-Garn, near Llanfair-y'nghornwy (disused).

Two disused quarries situated about 700 yards S.E. of Bonw, a mile S.W. of Llanfair-y'nghornwy Church. The site is two-thirds of a mile S.S.E. of the summit of Mynydd-y-Garn, and 275 yards W.N.W. of 'Gorlan-gôch' of the Old Series Ordnance one-inch map and of the six-inch map.

Maps: One-inch New Ser. Ordnance and Geological, 93; Old Ser. Geological, 78 N.W.; six-inch, Anglesey 2 S.W.

Latitude 53° 22′ 36″. Longitude 4° 31′ 42″.

The quarries are in rocks belonging to the zone of *Glyptograptus teretiusculus* (Glenkiln Series), according to Mr. Greenly. At or near the base of the Black Slates (*Nemagraptus gracilis* Beds), *i.e.*, a little higher, according to Dr. Matley.[1]

Dr. Matley describes the quarries as follows:—"In the more southerly exposure it [the ore] is a black oolitic ironstone or ferruginous mudstone, which passes upward into soft blue-black shale and downward into fine grit. About 8 or 9 feet of it contains oolitic grains, and there may be more oolitic rock concealed below the grit. The beds dip steadily north-westward at an angle of 58°.

"In the second exposure, 100 yards away to the north, the beds dip in the opposite direction, namely, south-eastward, at 20° to 30°. The oolitic rock is flaggy, and passes upward into grey grits that resemble the bottom beds of the exposure just described. It thus appears that the grit lies between two bands of ironstone.

"The zone appears to be not less than 20 feet thick. Unfortunately its base is not exposed. Black shales dip towards it as if to pass below it, but they may be cut off from it by faulting. The presence of grit suggests that its horizon is at or near the base of the Black Slates."

The following analyses, furnished by Messrs. E. J. Morris and W. E. Williams, B.Sc., are quoted from a proof of the forthcoming Memoir on the Geology of Anglesey by Mr. Greenly. The material analysed is described as "black oolitic ironstone, 275 yds. north-west of Gorlan-gôch, Mynydd-y-Garn":—

	Var. A.	Var. B.
SiO_2	41·80 ...	37·50
TiO_2	0·05 ...	—
Al_2O_3	16·18 ...	9·17
Fe_2O_3	4·28 ...	—
FeO	24·28 ...	29·90
FeS_2	0·56 ...	0·15
MnO	1·86 ...	trace
CaO	1·00 ...	1·25
MgO	0·43 ...	9·50
H_2O (hygroscopic and combined)	8·44 ...	—
CO_2	nil ...	6·66
P_2O_5	1·12 ...	0·81
	100·00 ...	94·94
Iron (metallic)	22·141 ...	23·235

The ore, being a bedded deposit, might have extended originally for a considerable distance; but the fact that Dr. Matley failed to find it on the slopes of Mynydd-y-Garn suggests that it is lenticular. Moreover, as the country is intensely disturbed by folding and faulting, it is unsafe to assume that the beds can be followed far from the quarries.

[1] *Quart. Journ. Geol. Soc.*, vol. lvii, 1901, p. 26.

The occurrence of ironstone hereabouts is indicated by a symbol on the Geological Survey map of 1852, though the symbol is placed at the Telegraph Station, about a quarter of a mile too far east. According to a local resident some few cart-loads of the ore were dug out about 40 years ago and taken to the coast for shipment, but were left there. There are no obvious difficulties in the way of working the ore.

The nearest railway station is Rhôs-gôch (L. & N. W., Amlwch Branch), 6 miles east by road. Valley Station (L. & N. W., Holyhead Branch) is 8 miles south by road. The coast is less than 2 miles away to the west.

Other Localities in Anglesey.

Mr. Greenly, in the Memoir already quoted, mentions thirteen other localities where ironstone, usually oolitic or pisolitic, occurs. He has favoured us with the following annotated list:—

One-inch New Series Map, Sheet 94 (Beaumaris).

Llangoed.—At Plâs-yn-Llangoed, about 600 yards S. of Llangoed Church, 3 miles N. of Beaumaris. Six-inch map, Anglesey 15 N.W. Proved in a boring that penetrated the Carboniferous Limestone and reached the Ordovician rocks.

Llanddona.—About $3\frac{1}{2}$ miles N.W. of Beaumaris. Six-inch map, Anglesey 14 N.E. Ironstone debris observed at a place 300 to 400 yards S.W. of the church. Debris of pisolitic ore occurs also in a lane near Bwrdd-Arthur (Llanfihangel), as noted by Ramsay; but the ore mentioned by him as visible in a little cove on the coast is merely a ferruginous grit, and not the same as the pisolitic ore. None of these Llanddona occurrences is of any economic importance.

One-Inch New Series Map, Sheet 93 (Holyhead).

Llangwyllog.—By Ty'n-yr-onen Farm, near Llangwyllog Station (L. & N. W., Amlwch Branch), 3 miles S.S.E. of Llanerchymedd. Six-inch map, Anglesey, 13 S.W. Latitude, 53° 17′ 10″. Longitude, 4° 21′ 15″. Zone of *Nemagraptus gracilis.*

Llandyfrydog.—At the Mill (Felin-esgob), $\frac{3}{4}$ mile N.E. of Llandyfrydog Church, $1\frac{1}{2}$ miles E.N.E. of Llanerchymedd. Six-inch map, Anglesey, 7 N.E. Latitude, 53° 20′ 55″. Longitude, 4° 19′ 35″. Glenkiln Shales. Workings filled in long ago. The presence of ironstone here is indicated by a symbol on the Geological Survey map published in 1852.

Rhôsybol.—(1.) At Pwll-côch-isaf, $\frac{3}{4}$ mile S.S.E. of Rhôsybol. Six-inch map, Anglesey, 7 N.W. Latitude 53° 21′ 27″. Longitude, 4° 21′ 32″. Zone of *Nemagraptus gracilis.* The ironstone has not been worked for many years. (2.) Near Penbol, $1\frac{1}{2}$ miles W. of Rhôsybol. Six-inch map, Anglesey, 7 N.W. Latitude, 53° 21′ 45″. Longitude, 4° 24′ 0″. Ironstone ex-

posed by the side of the alluvial flat a quarter of a mile S.E of the farm-house. Glenkiln Shales, which dip N. at 45°. The site is within half-a-mile of the L. and N. W. Railway (Amlwch Branch).

Rhodogeidio.—By stream in valley half-a-mile E. of Gwredog, $1\frac{1}{2}$ miles N.W. of Llanerchymedd. Six-inch map, Anglesey, 7 N.W. Latitude, 53° 20′ 55″. Longitude, 4° 23′ 15″. Glenkiln Shales, which dip N.E. at 40°.

Llanbabo.—(1) In elbow of lane, 700 yards S.S.W. of Llanbabo Church, 3 miles N.W. of Llanerchymedd. Six-inch map, Anglesey, 6 S.E. Latitude, 53° 20′ 50″. Longitude 4° 26′ 20″. Glenkiln-Hartfell Series. A ferruginous grit, which dips N.N.E. at 30°.

(2.) North side of road west of the farm-yards at Fferam-uchaf, nearly a mile W. of Llanbabo Church. Six-inch map, Anglesey, 6 N.E. Latitude, 53° 21′ 6″. Longitude, 4° 27′ 35″. Zone of *Nemagraptus gracilis*. Dip N.N.E.

The symbol for iron ore engraved on the Geological Survey Map of 1852 at Yr-efail, $\frac{3}{4}$ mile N.E. of Llanbabo Church, probably relates to some ferruginous grits, and not to pisolitic ore.

Llanfflewyn.—At Ucheldref-uchaf, a mile S. of Llanfflewyn, 5 miles N.W. of Llanerchymedd. Six-inch map, Anglesey, 6 N.E. Latitude, 53° 21′ 33″. Longitude, 4° 28′ 38″. A very poor exposure of Glenkiln Shales on the N. side of a hedge about 300 yards E.N.E. of the farm-house.

Cemaes.—(1.) About 100 yards N.W. of Pen-terfyn, half-a-mile E. of Llanbadrig Church. Six-inch map, Anglesey, 2 N.E. Latitude, 53° 25′ 25″. Longitude, 4° 26′ 0″. Small quarries in flaggy oolitic ironstone, 17 ft. thick. Zone of *Nemagraptus gracilis*. Noted by Dr. C. A. Matley.

(2.) On the foreshore of Porth-Padrig, Cemaes Bay, and about 300 yards S. of Llanbadrig Church. Six-inch map, Anglesey, 2 N.E. Latitude, 53° 25′ 15″. Longitude, 4° 26′ 40″. Covered at high water. Zone as above. Noted by Dr. C. A. Matley.

Amlwch.—In Porth-pridd, on E. side of Porthwen Bay, 3 miles W.N.W. of Amlwch. Six-inch map, Anglesey, 3 N.W. Latitude, 53° 25′ 28″. Longitude, 4° 23′ 45″. Black oolitic ironstone. Zone as above. Noted by Dr. C. A. Matley.

Of the various outcrops of ironstone in Anglesey noted above, Mr. Greenly remarks that those on the northern coast are pale-green or grey siderite-rocks, feebly oolitic, and not at all promising from an economic point of view. Those at Llanbabo are ferruginous grits containing quartz, and are feebly oolitic. The rest are heavy black oolites, those of Llangoed (Bryn-celyn) being coarse pisolites. All the ironstones tend to graduate into heavy black shales or into fine angular grits. The ore exposed in the lane S.S.W. of Llanbabo proved to contain 26·99 per cent. of

Fe_2O_3, equal to 18·89 of iron. The ore at Llandyfrydog Mill, analysed in 1870, gave the following results:—

SiO_2	17·30
Al_2O_3	11·00
Fe_2O_3	48·08
FeO	5·47
MnO	2·52
CaO	1·62
MgO	1·11
P_2O_5...	1·46
SO	0·28
Water (hygroscopic)	2·20
„ (combined)	8·54
	99·58
Iron (metallic)	37·92

A specimen of pisolitic iron ore "from near Llanerchymedd," analysed in 1872 by Prof. Story-Maskelyne and Dr. Flight[1], gave the following results:—

Silica	13·917
Silica (combined)	1·799
Phosphoric acid	11·364
Carbonic acid	16·038
Iron oxide	10·566
Iron protoxide	28·946
Chromium oxide	trace
Lime	12·309
Magnesia	1·914
Water and organic matter	4·084
	100·937
[Iron (metallic)	29·9098]

The exact locality cannot be stated, as there are several outcrops near Llanerchymedd.

There is doubtless a large amount of quartz in all these ironstones. Probably the most promising locality is Mynydd-y-Garn; next to it Gwredog, as it is easy of access by rail. None of the ironstones seem to have been worked on a commercial scale, though some had been opened up in trials as far back as 1852.

Carnarvonshire.

The remarks regarding the geological structure of Anglesey as it affects the range and reserves of the pisolitic ores (p. 13) apply equally to Carnarvonshire. The ores in this county are known to occur in five different districts: (1) the Llandegai and Aber district near Bangor, (2) the Bettws Garmon district near Carnarvon, (3) at Llanengan near Abersôch, (4) at Trwyn-y-tâl near Nevin, and (5) at Tremadoc. The ores at Llandegai and at Bettws Garmon were being vigorously worked in 1917; that at Aber was being opened up; at Llanengan and Trwyn-y-tâl the industry has been dormant for many years; while at Tremadoc the best of the ironstone has probably been long ago worked out.

[1] *Journ. Chem. Soc.*, new series, vol. x, 1872, p. 1055.

Penrhyn Iron Mine, Llandegai, near Bangor.

The Silurian Iron Ore Co., Ltd., 45, Wind St., Swansea[1].

Openworks, day-levels and a slant immediately north of Rhôs-uchaf Farm, about three-quarters of a mile S.W. of Llandegai Church, 1½ miles S.E. of Bangor. Nearest railway station: Bangor (L. & N.W.), 3 miles by road.

Maps: One-inch New Ser. Ordnance, 106; Old Ser. Geological, 78 S.E.; six-inch Carnarvonshire, 7 S.W.

Latitude 53° 12′ 30″. Longitude 4° 6′ 20″.

The ore occurs as a bed, probably of Ordovician age, which varies in thickness from 14 ft. down to as little as 4 ft. where compressed by the folding. It has been thrown into a series of sharp anticlines and synclines, the axes of which trend a little east of north and west of south, and pitch east of north. Some repetition of the beds by overthrusting is observable. There are also several small cross-faults. The general dip is a little south of east. All these structural features are excellently shown in the openworks, which extend along the outcrop for several hundred yards. The sequence of the strata is best seen at the top of the slant, where the following measurements were made, in descending order:—

	Ft.	Ins.
Gravelly boulder-clay, about	10	0
Black shale (elsewhere at least 12 ft.)	5	0
Red pisolitic iron ore, 11 ft. 3 ins. (working)	14	0
Flaggy shale alternating with black pisolitic iron ore, 9 ins. (rejected)		
Black pisolitic iron ore, 2 ft. (working)		
Black mudstone, with nests and balls of iron pyrites ...	0	11
Shales, mudstone, grits, &c.	—	—

Everywhere a band of iron pyrites, usually about 6 in. thick, underlies the black ore and forms the floor on which it rests.

There are two varieties of ore—red and black, the average proportion being 8 ft. of red ore on 4 ft. of black. Both are sent out together.

The quality of the ore varies considerably, the silica rising occasionally beyond a permissible limit. The average composition aimed at is: iron 38 per cent., silica 16 to 18, sulphur 1, and phosphorus 1 to 1·5. During the period 1913-1917 the ore has shown the following average percentages: iron 38, silica 17, sulphur 1, phosphorus 1, loss [? combined water] 12, moisture 4.

Reserves presumably lie eastward, in which direction the ore-bed has been followed in the slant for a depth of about 40 yards. To the west the bed crops out, but folding may bring it in again. Northward and southward, in lower ground, nothing is known as to the course of the outcrop. There is property still unworked, as at present the output has come from the openworks and the shallow levels. The slant will give access to ore at deeper levels.

The mine was opened in Sept., 1913, as the result of the discovery of iron-ore on the surface by Mr. E. J. Morris, of Bangor.

[1] Manager, Mr. Alex. Mackay, to whom we are indebted for analyses and other information respecting this and the Ystrad Mine (p. 22).

The ore is won by openworks and levels, and that at a depth will be reached by the slant. Explosives are employed when necessary. The thrusts and cross-faults give some trouble as the ore is followed in the levels. There is a little over-burden of boulder-clay. Some shale partings in the black ore are picked out by hand when separable, and nests of pyrites are removed. At present water presents no difficulties.

The ore is run in tubs on rails down an incline, about 150 yards long, the full tubs pulling up the empties. It is then drawn along a level tramway, about 500 yards long, which connects the foot of the incline with the Bangor-Bethesda road, where it is shot into carts and taken about 200 yards to the Penlan siding on the L. and N. W. Railway (Chester and Holyhead Branch).

The average weekly output during the years 1915-1917 has been about 200 tons. During the first three years the bulk of the ore was smelted at Brymbo, but a little was sent to Messrs. Baldwins, Ltd., at Landore, Swansea. Subsequently the whole output has been taken by the latter firm.

Aber Mine.

Mr. E. J. Morris, F.G.S., Llwyn-celyn, Aber Road, Bangor.

Openworks and day-levels, about $\frac{3}{4}$ mile E.N.E. of the church at Aber, $4\frac{1}{2}$ miles E. of Bangor. The mine is situated in Coed Tan-yr-allt. Nearest railway station: Aber, $1\frac{1}{2}$ miles by road.

Maps: One-inch New Ser. Ordnance 106; Old Ser. Geological 78 S.E.; six-inch Carnarvonshire, 7 N.E.

Latitude, 53° 14′ 10″. Longitude, 4° 0′ 10″.

There are three short levels, numbered 1, 2, 3, in order from E.N.E. to W.S.W. In No. 1 the beds dip E. 20° S. at 60°. This direction appears to hold in Nos. 2 and 3, but the amount of dip varies. In No. 1 level a fault approximately parallel to the strike causes the shale and ore to turn up and become inverted; the fault cuts off the ore, but from the nature of the shale beyond the fault it is believed that the ore will be recovered a little farther inwards. The other levels show faults repeatedly, some being apparently thrusts from the south-east. In No. 3 level a six-inch band of pale yellowish ochreous rock (? ash) runs vertically up the present face (8th Aug., 1917) and strikes along the direction of the level (about S.S.E.), but is separated from the beds in the outer part of the level by a fault. On the whole the ore-bed appears to dip into the hill in a south-easterly direction, but to be cut by strike-faults, probably thrusts from the S.S.E., so that it runs up the hill obliquely in a south-westerly direction.

The ore-bed, 13 ft. thick, is associated with shales, mudstones, and igneous rocks, believed to be of Ordovician age.

The ore may be the same bed of pisolite as that formerly worked at Rhiwiau, Gorddinog, $\frac{3}{4}$ mile to the east. In the opposite direction (towards Aber) the outcrop is believed to extend for at least 300 or 400 yards before passing into another property. The reserves presumably lie to the south-east, which appears to be the general direction of dip.

The chief obstacles to mining are the strike-faults, which cut off the ore and necessitate much exploration work. So far there is no trouble with water. It is proposed to drive a low-level adit, which will drain the mine and prove the ground. There is a considerable amount of downwash on the slope of the hill and this would be troublesome in open working. Trial boreholes have been put down.

The mine was commenced in 1916, and at the time of our visit (Aug., 1917) there was no regular output, but a few tons of ore had been brought to the surface.

By Aug., 1918, a number of new trials had been made, showing ore at fresh places and confirming the view that it is a bedded deposit. On top of the hill that rises above the 800 ft. contour, about one-third of a mile east of Maes-y-gaer, a new outcrop of pisolite, believed to dip northward, had been discovered. In the same locality an outcrop of manganiferous spathic ore had been found, which is said to contain 40 per cent. of iron and 8 to 10 of manganese, the phosphorus being low. The relations of these new finds to the pisolite of the Aber mine are at present unknown.

A tramway worked by an endless rope may be laid from the levels along the path to the east end of the wood, near Tan-y-clogwyn Cottages, and the ore conveyed by road-tractors to the railway. An alternative would be the construction of an aerial ropeway direct from the mine to the railway, about half-a-mile distant, on lower ground.

Gorddinog Mine, Llanfairfechan (disused).

Mr. E. J. Morris, F.G.S., Llwyn-celyn, Aber Road, Bangor.

Openworks and day-level at Rhiwiau, $1\frac{3}{4}$ miles E. by N. of Aber Church and a mile S. by W. of Llanfairfechan Church. Nearest railway stations: Aber, and Llanfairfechan (L. & N.W.), each about $2\frac{1}{2}$ miles by road.

Maps: One-inch New Ser. Ordnance 106; Old Ser. Geological 78 S.E.; six-inch Carnarvonshire, 7 N.E.

Latitude, 53° 14′ 12″. Longitude, 3° 58′ 45″.

The pisolitic iron-ore is possibly the same as that found at the Aber mine. At Rhiwiau the bed crops on the steep side of a valley and dips E. 20° S. at a high angle. Its thickness is reported to be 22 or 23 ft. The ore contains a quantity of iron pyrites, but this is said to occur in part only of the bed. The pisoliths are larger and more scattered than those at Aber Mine.

There are presumably large reserves in the direction of dip and along the strike to the north-east. A considerable stock of ore has been stacked at the mine.

The ore was got mainly by openwork, but a level also was begun. The mine was worked for a few months only, and closed down in Nov., 1916. The ore had, in part, to be hand-dressed to rid it of the pyrites. It was sent to Brymbo Iron Works.

Ystrad Mine, Bettws Garmon.

The Silurian Iron Ore Co., Ltd., 45, Wind St., Swansea.

Openworks and day-levels about ¼ mile south-east of the church at Bettws Garmon, 5 miles S.E. of Carnarvon. Nearest railway-station usually Bettws Garmon (¼ mile by road) on the North Wales Narrow Gauge Railway; but the nearest available stations in 1917 were Dinas Junction (L. & N. W.) 5 miles by road, and Carnarvon, 5½ miles by a better road.

Maps: One-inch New Ser. Ordnance 106; Old Series Geological 78 S.E.; six-inch Carnarvonshire 16 S.E.

Latitude, 53° 5′ 35″ to 53° 5′ 49″. Longitude, 4° 10′ 35″ to 4° 11′ 0″.

The ore-bed lies in the Lower Lingula Flags (Cambrian) according to Prof. Fearnsides. It is from 6 to 15 ft. thick, with slates above and below. In places it is duplicated or triplicated, but it is not known whether this is due to the intercalation of shale-bands or to repetition by small overthrusts from the south-east: probably the latter, for the duplication dies out rapidly along the strike.

The ore-bed dips towards the south-east at 30° to 90°, the average angle being about 54°, as measured in No. 3 level towards the upper (north-east) end of the openworks. There are indications of small overthrusts nearly parallel to the strike, also of sharp folds and small cross-faults. A few igneous dykes cut diagonally across the ore-bed; one in No. 2 level is 8 ft. wide. Some of these dykes occupy lines of fault. Occasional small quantities of chalybite are found, especially in Nos. 2 and 4 levels. When fresh it is of a pale-yellow or buff colour, but becomes brownish-red after exposure.

The pisolitic ore here is similar to that of the Penrhyn Mine (p. 19), but is more costly to work owing to its greater hardness. The ore has shown the following average percentages during 1913-1917: iron 38, silica 20, sulphur 1, phosphorus 1·5, loss [? combined water] 10, moisture 3. The ore crops out towards the north-west, but in the opposite direction extends for an unknown distance. At present the workings are shallow and follow the outcrop up the steep side of the valley towards the north-east until at the parish boundary they pass into Gareg-fawr property. Towards the south-west the outcrop descends to the bottom of the valley and is probably buried under drift and alluvium.

Ironstone appears to have been worked intermittently (presumably for iron-ore) for at least 77 years at Bettws Garmon, for the Ordnance map (78 S.E.) published in 1841 shows, north-east of Ystrad, an "Ironstone quarry," though this may have been what is now the Gareg-fawr Mine (p. 23). The Ystrad Mine first appears by name in the Home Office Statistics in 1911, and probably earlier references to the ironstone output at Bettws Garmon refer to the Gareg-fawr workings. The Ystrad Mine was taken over by the present company from the Bettws Garmon Iron Ore Co. in 1913.

The ore is won by open cuttings and by short levels or galleries driven into the hill-side; of these there are eight, numbered from above downward. The ore is excavated by overhand stoping. There is little trouble in working it; the faults cause no serious difficulty, and the water drains away down the valley-side. Timbering is unnecessary, an occasional pillar of ore or dyke-rock being left to support the roof.

Some of the ore is crushed to four-inch lumps in a jaw-crusher driven by a dynamo worked by a gas-engine. None of the ore is calcined. A German calcining-kiln, bought by a previous company and tried, proved to be a failure.

The output in 1917 was about 300 tons a week, an amount greater than in pre-war times. The ore is put into trucks at an adjacent siding on the N.W.N.G. Rly. and conveyed about 5 miles to Dinas Junction (L. & N.W.), where it is reloaded into trucks of standard gauge. Formerly some of the ore was sent to Brymbo; but in 1917 the whole output went to Messrs. Baldwins, Ltd., Landore, Swansea.

Gareg-fawr Mine, near Bettws Garmon (disused).

Mr. W. J. Roberts, Bryn Meddyg, near Bangor.

Openworks and day-levels north-east of the Ystrad Mine, from which it is separated by a wall forming a boundary between the parishes of Bettws Garmon and Waen-Fawr. Higher up the side of the valley than the Ystrad Mine.

Maps: As for the Ystrad Mine (*q.v.*).

Latitude, 53° 5′ 55″. Longitude, 4° 10′ 30″

The two mines are in the same geological formation and on the same ore-bed, but the dip is less at Gareg-fawr.

It is probable that references to iron-ore having been dug at Bettws Garmon at intervals for over 50 years refer to this property.

In 1854 the mine was being worked by the Aberdare Iron Co., the ore being shipped to South Wales for mixture with the clay ironstones of that district.

The mine has been disused since 1913, when Messrs. Alfred Hickman, Ltd., near Wolverhampton, ceased to work it.

In the Mineral Statistics, Bettws Garmon is first mentioned in 1860, though still earlier references to Carnarvonshire may apply to this place. Gareg-fawr first appears by name in the Statistics for 1900. The outputs have been already given on p. 12. In 1900 the percentage of iron is quoted as 45; in 1901 as 46; in 1902 as 43, and in 1908 as 41·34. In 1909-13 it was 40.

Towards the end of the 1908-13 period the ore was transported by aerial ropeway about 2½ miles north-eastward over the mountain, and delivered at Llanberis Station (L. & N.W.). The ore at that time was smelted at Messrs. Hickman's works.

The following analysis of oolitic magnetic ore from Gareg-fawr, made by a Dr. Price of Newport, was published by Prof. Haughton in 1854:—

Loss by ignition (carbonic acid, organic matter, &c.)	7·90
Clay and silica	12·90
Peroxide of iron	34·14
Protoxide of iron	32·90
Alumina	3·66
Lime	5·00
Magnesia	1·00
Phosphoric acid	2·25
Sulphur	0·25
Arsenic	trace
	100·00
Iron (metallic) in raw ore	49·50
,, ,, roasted ore	53·74

Tyddyn-bâch Mine, Bettws Garmon.

Mr. W. J. Roberts, Bryn Meddyg, Bangor.

Situated at Tyddyn-bâch, on the south-western side of the Gwyfrai Valley, about half-a-mile S.W. of Bettws Garmon Church.

Maps: One-inch New Ser. Ordnance 106; Old Ser. Geological 78 S.E.; Six-inch Carnarvonshire 21 N.W. (Tyddyn-bâch Farm is on 16 S.W.).

Latitude, 53° 5′ 18″. Longitude, 4° 11′ 30″.

This is an open quarry situated on a continuation of the outcrop worked at Ystrad, across the valley. The bed is here 18 ft. thick and dips to the S.E. at 83°. The ore is said to contain 30 per cent. of iron. At the time of our visit (14th Aug., 1917) ore had not been sent away, but some 2,000 tons were ready for despatch.

A short distance to the south-west of the quarry there is another opening on the ore-bed, under the same ownership.

Cwm-bychan, Bettws Garmon.

In August, 1917, Messrs. E. J. Morris and T. H. Roberts were carrying on explorations for ironstone near Cwm-bychan, about a mile south-east of Bettws Garmon. The locality falls within the New Series one-inch Ordnance map, Sheet 119; Old Series Geological 75 N.E.; six-inch Carnarvonshire 21 N.E. The site was not visited, but the bed is presumably different from that worked at Bettws Garmon.

Tan-y-fron Quarry, Llanengan, near Abersôch (disused).

A disused quarry, about 50 yards N.E. of the Rectory, Llanengan, 1¼ miles S.W. of Abersôch, 6 miles S.W. of Pwllheli. Nearest railway station: Pwllheli (Cam. Rys.), 8 miles by road.

Maps: One-inch New Ser. Ordnance 134; Old Ser. Geological 75 S.W.; six-inch Carnarvonshire 45 S.W.

Latitude, 52° 48′ 57″. Longitude, 4° 31′ 50″.

The quarry is in rocks of Ordovician age (Zone of *Nemagraptus gracilis*). In this district the pisolitic iron-ore has been broken

up by earth-movements into lenticular masses, and in the quarry it has been brought on to Llanengan Mudstones (Arenig Series) by a thrust-plane. Above the ore-bed the rocks are so crushed that all original structures have disappeared.

The Tan-y-fron quarry is divided into two sections. In the more westerly one, where the beds show a south-easterly dip of 35°, about 16 ft. of iron-ore are visible, and a few feet below is a bed of manganese-ore, about 3 ft. thick, but variable, and in places thicker. The manganese seems to be cut out by faults, but comes in again at the top of the quarry.

In the more easterly section of the quarry, a few yards farther on, ironstone is seen, parallel to that in the other part of the quarry, and resting on about 3 ft. of manganese ore.

The iron-ore lenticles crop out almost continuously from Pen-y-gaer south-south-westwards as far as Llanengan Rectory,[1] a distance of three-quarters of a mile, while other masses occur along a belt of ground running from Llanengan in an east-south-eastward direction past Hendy-Capel (where the ore-beds range up to 12 or 15 ft. in thickness) and Deugôch for half a mile. In the Llanengan Mudstones also there are two ore-masses south of Porth-fawr, two miles east of Llanengan. The Llanengan iron-ore was known as early as 1851, for its presence is noted on the Geological Survey map of that date. It appears to have been proved in a number of trial holes and levels, but to have been little worked. It is said to contain too much iron pyrites to be of commercial value. The ore was described in 1854 by Prof. S. Haughton. Access to the quarry is bad.

A sample of pisolitic iron-ore "from Pwllheli," analysed in 1872 by Maskelyne and Flight,[2] gave 31·349 per cent. of metallic iron. The nearest known sources of pisolitic ironstone from which this sample could have been obtained are the Llanengan district, and Trwyn-y-tâl, Llanaelhaiarn. An analysis of the Llanengan ore has been given on p. 6.

Merioneth.

The Merioneth pisolitic ores are known in two districts: one at Penyrallt near Penrhyndeudraeth, the other along the northern slopes of Cader Idris, near Dolgelley. The Penyrallt ore appears to have received a fair trial about 40 years ago, but was found to be too high in sulphur. Those from near Dolgelley have been worked, but difficulties of transport seem to have led to their being abandoned.

Penyrallt Iron Ore Mine, Llandecwyn (disused).

Two openworks respectively 150 yards N.E. and 200 yards S.W. of Penyrallt Farm, half-a-mile E. of Llanfrothen Church and 2 miles N.E. of Penrhyndeudraeth. Nearest railway stations: Penrhyndeudraeth, on the Ffestiniog Narrow Gauge Railway, 1½ miles to the south-west, and a station of the same name on the Cambrian Railway, half-a-mile farther.

[1] T. C. Nicholas, *Quart. Journ. Geol. Soc.*, vol. lxxi, 1915, pp. 83–143.
[2] *Journ. Chem. Soc.*, New Series, vol. x, 1872, p. 1056.

Maps: One-inch New Ser. Ordnance 119; Old Ser. Geological 75 N.E.

(1.) Six-inch Merioneth 11 N.E. Latitude, 52° 57′ 1″. Longitude, 4° 2′ 18″.

(2.) Six-inch Merioneth 11 N.W. Latitude, 52° 56′ 52″. Longitude, 4° 2′ 30″.

Penyrallt is a small farm near a conspicuous chimney and engine-house belonging to the Catherine shaft of the disused Bwlch-y-plwm mine on a lead-vein.

The ore-bed is overlain by grey slates and lies on or close above an igneous rock. The slates are probably of Ordovician age.

(1.) The *north-east openwork* shows a bed of black pisolitic ore dipping W. 20° N. at 20° to 25°. The bed has been deeply quarried for about 50 yards along the crop in a north-eastward direction, but to a depth of only about 6 ft. at the north-east end, where the quarrying was stopped at a wall. The thickness of the ore is uncertain. It appears to be intimately mixed with finely-divided pyrites. The pisolitic structure is feebly developed.

North-eastward the ore is said to continue along the strike, but south-westwards it is presumably thrown out of its course by the lead-vein mentioned above (this is the most southerly vein of several shown on the geological map).

(2.) The *south-west openwork* shows a similar and presumably the same bed. It has been worked by a long deep trench extending to the north-east along the crop and with a drift leading to the north-west from the bottom. The rocks dip N. 35° W. at about 60°. The ore, which lies on igneous rock, appears to be 6 to 10 ft. in thickness. It is apparently faulted on the north-east against igneous rock resembling the seat-rock.

There is a tip of ore containing good blocks of coarse strongly-marked oolite and pisolite. Pyrites was not noticed.

The ironstone was being worked about the year 1846, and again some 40 years ago. We are informed that the ore has been thoroughly tested for smelting at Brymbo, but was found to be too sulphurous.

Mr. H. J. Wright, of Llanbedr, Merioneth, has kindly supplied the following old analysis of "Penyrallt Iron Ore" by a chemist at the Mostyn & Darwen Iron Works:—

Peroxide of iron [Fe_2O_3]	22·50
Protoxide of iron [FeO]	30·22
Sulphide[1] of iron [FeS]	2·61
Peroxide of manganese [MnO_2]	1·09
Alumina	10·20
Silica	20·90
Lime	1·05
Phosphoric acid [P_2O_5]	2·574
Combined water and carbonic acid	8·28
Alkalies estimated	0·576
	100·000
Metallic iron	40·9
Manganese	0·687
Sulphur	0·95
Phosphorus	1·124

[1] To give an equivalent iron percentage of 40·9 and a sulphur percentage of 0·95 the sulphide must have been estimated as FeS, not as FeS_2.

The ore was presumably carted to Penrhyndeudraeth or to Portmadoc for shipment, or dispatched from the former by rail. An inclined tramway could easily be constructed from the openworks down to the Ffestiniog Narrow Gauge Railway, 300 or 400 yards to the south.

Ffordd-ddu, near Arthog (disused).

A small quarry and some trial-holes situated by the side of the road called Ffordd-ddu, a quarter of a mile S. of Planwydd-helyg and $1\frac{1}{4}$ miles S. 22° E. of Arthog Station (Cam. Rys.).

Maps: One-inch New Ser. Ordnance 149; Old Ser. Geological 59 N.E.; six-inch Merioneth, 36 S.E.

Latitude, 52° 41′ 45″. Longitude, 4° 0′ 5″.

The geological formation is probably the same as that at Cross Foxes (*below*). In the quarry, lenticles of pisolitic iron ore and nests of large pisoliths occur in slate. The lenticles are 2 or 3 ft. thick, and appear to be bounded by thrust-planes. The structure of the beds is complex. The direction of strike is north-east and south-west. The dip is very high, but the angle is uncertain. The ore is separated by a few feet of slate from pillow-lava, which, though found both above and below the ore in the quarry, is (according to Dr. A. H. Cox's information) stratigraphically below the ore.

The ore, being a bed, continues for some distance, and has been found by Dr. Cox at intervals all the way from here to Cross Foxes (a distance of 7 miles), on the whole improving in that direction. It is, however, broken by faults and igneous intrusions.

The occurrence of ironstone here is shown by a symbol on the Geological Survey map published in 1850-55. According to local information the place was worked by two men for a short time about 12 years ago.

Bwlch-gôch, near Dolgelley (disused).

This mine, situated $1\frac{1}{2}$ miles S.E. of Dolgelley, yielded 500 tons of ore in 1912 and 391 tons in 1913, with an average iron percentage of 39. The mine was not visited.

Cross Foxes Mine, near Dolgelley (disused).

Openworks and a level situated at Bryn-castell (Brithdir Parish), half-a-mile S.W. of the Cross Foxes Inn, $2\frac{1}{2}$ miles E.S.E. of Dolgelley. Nearest railway station: Dolgelley (Cam. Rys.).

Maps: One-inch New Ser. Ordnance 149; Old Ser. Geological 59 N.E.; six-inch Merioneth, 37 N.E.

Latitude, 52° 43′ 55″. Longitude, 3° 50′ 10″.

The rocks belong probably to the Dicranograptus Shales (Glenkiln Series), according to information supplied by Dr. A. H. Cox.

The ore, which is a bedded pisolite, was worked in narrow open trenches following the outcrop, which runs in a north-east and south-west direction. The first (north-east) trench, which is 20 ft. deep on one side and about 40 ft. on the other, shows the strata to be somewhat curved, the dip at the surface being 40°, while at the bottom of the openwork it is about 60°. The

upper 7 ft. of the ore-bed, which is 20 ft. thick, appears to have been worked separately, as if of better quality than the rest. There are indications of a pyrites floor, but this has been much weathered. The ore overlies dark shale and is overlain by volcanic ash. A level, now flooded, was driven at a depth of about 60 ft. below this openwork, presumably to win the ore at a depth.

In the second openwork, a few hundred yards farther to the south-west, the ore-bed is practically vertical. This trench is not quite in line with the other, as if a small dip-fault crosses the intervening ground and throws the crop out of course.

A third openwork and some old shafts show the direction of the bed, as does also a line of springs.

The following analysis, which is believed to be thoroughly representative, as it is the average of a large number of analyses taken from large consignments, has been kindly supplied by the Brymbo Steel Co.:—

SiO_2	22·80
FeO	27·64
Fe_2O_3	20·00
MnO	0·465
CaO	6·50
MgO	2·10
Al_2O_3	8·64
P_2O_5	3·69
Sulphur	1·045
Loss on ignition	6·70
	99·58
Iron (metallic)	35·5
Phosphorus	1·61

The occurrence of iron-ore here is indicated by a symbol on the Geological Survey map published in 1850-55. The ore was being worked about 1870-80, and was sent to the New British Iron Co.'s furnaces at Ruabon. Later it was smelted at the Round Oak furnaces in South Staffordshire. During the years 1908-10 it was worked by the Brymbo Steel Co., who raised during that period over 12,000 tons. About the year 1913 the road from the mine began to give way, and the cost of repairs was so great that, although a tram-line was laid over the peaty ground, working was discontinued.

Tyllau-mwn Mine, Drwsynant, near Dolgelley (disused).

Openworks, day-level and shaft in Cwm-ochr and two miles S.E. of Drwsynant Station (G.W.R.).

Maps: One-inch New Ser. Ordnance 136; Old Ser. Geological 73 S.W.; six-inch Merioneth 34 S.E.

Latitude, 52° 46′ 10″. Longitude, 3° 42′ 50″.

The geological formation is probably the same as that at Cross Foxes (p. 27). The openwork is about 25 yards long and 20 ft. deep, and the ore-bed, which is 8 to 9 ft. in thickness, is nearly vertical, and strikes about north-east and south-west. The foot-wall is of volcanic ash.

The ore is said to be the best in the county. An analysis, made early in 1910, of a 5 ton sample gave 52·1 % of metallic iron, while a bulk-analysis by the Ebbw Vale Iron Co. of ore containing rough stuff gave 44·8 % of metallic iron, 0·8 sulphur, 0·62 phosphorus, and 17·8 insoluble. We are indebted to the Ebbw Vale Co. for the following analysis (3rd Sept., 1909) of what is believed to have been a sample of ore from Drwsynant, but which may have come from Bettws Garmon:—

SiO_2	13·70
FeO	10·88
Fe_2O_3	50·83
Al_2O_3	7·23
MnO	trace
CaO	4·90
MgO	1·36
SO_3	0·096
P_2O_5	4·10
Combined water &c.	7·15
	100·246
[Metallic iron	44·043]

Not many yards to the south-west of the openwork some trials failed to find the ore, which is apparently cut out by a cross-fault. To the north-east of the openwork other trials have shown that the ore continues for at least several hundred yards.

About 70 ft. below the openwork a level was driven in the ore, and was reached by a cross-measure drift 50 yards long. In the level is a shaft 18 ft. deep.

The existence of iron ore here appears to have been known as early as 1838, as the name Tyllau-mwn ('the mine-shafts') is engraved on the Ordnance map of that date. The ore was being raised about 42 years ago. Twenty years later the place was explored by the British Mining Syndicate. About ten years ago it was taken over by Mr. T. H. Roberts, of Dolgelley, who sent away some 100 tons of ore.

CHAPTER IV.

CARBONIFEROUS BEDDED ORES.

INTRODUCTION.

By W. Gibson.

The use of the bedded ironstones of the Carboniferous rocks as a source of iron is of ancient date. On the replacement of wood by coal in smelting, a practice introduced by Dud Dudley in 1619, these ores became of great importance and their use gradually superseded that of the Sussex and Wealden ores. At the present day, they, in turn, have given place to the Mesozoic ores of the eastern counties, not only in furnaces situated at a distance from the coalfields, but in those once supplied with ores chiefly obtained from the neighbouring coalfields. Nor does it appear likely that the Coal Measure ironstones will be reverted to until the Mesozoic ores approach exhaustion. In 1913, out of a total of 16,345,753 tons of ironstone raised, only 941,128 tons were obtained from the bedded Carboniferous iron-ores. Of this quantity the blackband ironstones of N. Staffordshire furnished 859,244 tons; while Derbyshire, producing 492,973 tons in 1871, yielded only 116 tons. The amount of local Coal Measure ores raised in Yorkshire, Staffordshire and Coalbrookdale is also much less in comparison with that of half a century ago.

In North Staffordshire the valuable blackband ironstones are extensively mined from pits which though raising coal can yet be classed as ironstone-mines, since the ore forms a considerable proportion of their output. Elsewhere, such ironstone as is obtained in coal-mining does not, as a rule, exceed 100 tons of ore for every 16,000 tons of coal brought to the surface. To even a less extent is it picked out in openworkings for clays; and open-cast working for ironstone has been entirely abandoned.

The amount of ironstone contained in the Carboniferous rocks of this country is undoubtedly great, far exceeding that remaining in other formations, but there are several drawbacks to its profitable extraction. Chief among these are (1) the thinness of individual beds and the amount of waste material left in working them; (2) the irregularity in the occurrence of any particular bed; (3) the compact nature of the strata; (4) the adherence of foreign deleterious substances, that must be removed mechanically or by weather. For these reasons the use of these ores is being more and more replaced by that of Mesozoic ironstones.

Staffordshire and Shropshire are the chief counties where the Coal Measure ironstones are smelted. In Yorkshire smelting of these ores is confined to the district of Low Moor. They have practically ceased to be used in the Sheffield district, in Derbyshire, Nottinghamshire and S. Wales. Warwickshire sends some ironstone into South Staffordshire, but it is long since any ore

was smelted locally. The remaining coalfields do not appear to have produced a sufficient output of ore to have received recognition in the statistics.

Ironstones are known to occur throughout the Carboniferous system, but are more abundant and more evenly distributed in the Middle Coal Measures than elsewhere. In Northumberland the Redesdale ironstone in the Carboniferous Limestone Series and some ironstone near the base of the Coal Measures were once extensively worked. In the remaining coalfields ironstones are restricted to the Lower and Middle Coal Measures, except in N. Staffordshire, where the blackband ironstones occur towards the base of the Upper Coal Measures, or at the top of the Middle Coal Measures of some authorities.

Where the floor composed of Carboniferous rocks has been reached below Permian or Triassic formations, deposits of iron-ore are occasionally encountered. They are seldom more than 2 to 3 in. in thickness if in bands, and generally occur as a single layer of nodules. The ironstone formerly worked at Patricroft, near Manchester, and the bed sunk through in the Shireoaks Colliery, near Worksop, appear to bear a similar relationship to the overlying Permian. At Patricroft a hæmatite bed, 2 ft. thick yielding 22 to 26 per cent. metallic iron and 40 per cent. carbonate of lime is described[1] as lying beneath 10 ft. of red and grey shales overlaid by Permian strata. It was used, mixed with Ulverstone hæmatite, partly as a flux. This bed has not been recorded in recent sinkings through the Permian rocks of Lancashire and is not now worked at Patricroft.

In the sinking at Shireoaks an ironstone, 15 in. thick, is mentioned as occurring 9 ft. below the base of the Magnesian Limestone and giving the following analysis[2]:—

Peroxide of iron	63·110
Lime	5·174
Alumina	4·170
Silica	6·545
Sulphuric acid	0·293
Phosphoric acid	0·083
Carbonic acid	9·702
Water (combined)	10·936
	100·013

The association of the ores with shales, clays (fireclay, clunch), and not infrequently with seams of coal, has already been mentioned. Beds of ironstone, however, are somewhat more capricious than those of coal; few of them maintain a valuable character far, and many that are worked in some districts, thin out or deteriorate within a comparatively short distance. The Black Shale and Brown Mine Ironstones of Derbyshire and Yorkshire occur in more or less continuous beds: the valuable Black Band Ironstones are confined to North Staffordshire and each band is restricted to a definite area (p. 67).

[1] 'The Geology of the Country around Bolton-le-Moors, Lancashire,' *Mem. Geol. Surv.*, 1862, p. 17.

[2] *Quart. Journ. Geol. Soc.*, vol. xvi, 1860, p. 140.

Scattered grains and spherules of clay-ironstone (argillaceous carbonate of iron) are of common occurrence among Carboniferous clays and shales; the deposition of iron-ores in payable beds is not so general. Such concentration of the ore takes the form of (1) bands or (2) nodules.

(1.) Bands of ironstone attain their chief development in the North Staffordshire Coalfield, where they range from 1 to 4 ft. in thickness and occasionally to as much as 7 ft. In other coalfields the bands seldom exceed 1 ft. in thickness and most commonly are not above 3 in. thick. These thin beds are seldom persistent, but three or more beds separated by shale or clay may be found in one district, though such layers may not extend into a contiguous area.

(2.) Nodules of clay-ironstone are abundant in the Lower and Middle Coal Measures, ranging from a few ounces to several hundredweights. They occur as separate nodules or arranged in rows ("rakes" of Derbyshire). The nodules are generally compact, homogeneous, varying in colour from light-brown to black and are frequently seamed with cracks containing iron-pyrites, copper-pyrites, zinc-blende, galena, sulphide of nickel, sulphates of barium and lime, and magnesium and various carbonates, chiefly those of calcium, all of which however except carbonate of calcium occur in minute quantities. Some also are associated with oil-shale and contain traces of free oil.

Fragments of shale or clay usually adhere to the nodules, but fall off on exposure to the atmosphere. The time requisite varies, but the adhesion of shale to the nodules, especially to those obtained in deep mining, always adds considerably to the expense of preparing the ore for the smelter.

The iron-ore consists essentially of ferrous carbonate in intimate admixture with carbonate of lime and magnesia, silicate of alumina in the state of clay, manganic oxide, phosphoric acid, bisulphide of iron, a little water of combination and organic matter. When the organic matter rises to or exceeds 10 % they are termed blackband ironstones. The latter are comparatively of rare occurrence and are only persistently developed in North Staffordshire. In this, as in other coalfields, ordinary clay-ironstones occasionally pass locally into blackbands or semi-blackbands. The Burnwood Ironstone (p. 70) of North Staffordshire affords a good example of this local change.

An average composition of clay-ironstones other than blackbands gives as the more important commercial constituents: iron 30 to 35 per cent., silica 6 to 15 per cent., alumina 1 to 10 per cent. Lime, phosphorus and sulphur are low; manganese is usually present and runs as high as 0·2 per cent. Compared with the Mesozoic ores of Lincolnshire, Leicestershire and Northants, these ores are richer in iron than the Frodingham stone and not so rich as that of Northants. They are less siliceous and limy than any of the Mesozic ores, and contain about the same proportion of phosphorus, sulphur and alumina, but as a whole are

decidedly richer in manganese. Some of the ironstones occasionally contain as much as 1 per cent. of potash. Several analyses of ironstones are given in subsequent pages.

Besides being got from coal-mines the blackband ironstones of North Staffordshire sometimes constitute the chief or only output of a mine. Nearly all of the other clay-ironstones are obtained from coal-mines, only a small proportion coming from clay-pits. Open-cast working, which yielded a considerable bulk of clay ironstone in the past, has ceased. In some cases special methods of working are adopted, but as a rule the same principles are used as in coal-mining.

The blackband ironstones are calcined before delivery to buyers. Other clay-ironstones are often delivered in the raw state. Calcination is generally affected in the open, but sometimes in kilns, after exposure to weather to remove adhering fragments of shale, clay or sand-rock. In calcination blackbands lose about 50 and other clay-ironstones about 30 per cent. of their weight.

CHAPTER V.

CARBONIFEROUS BEDDED ORES (*contd.*).

Details.

Northumberland and Durham.

By W. Gibson and R. L. Sherlock.

Rich in veinstone, the northern counties, even in the earlier stages of the iron-industry, have never yielded a sufficient quantity of bedded ore to meet the consumption of the blast furnaces of the district. Reliance on native ores has resulted in failures, due in all cases to the limited distribution and rapid exhaustion of any particular deposit. All of these bedded ores have long ceased to be used.

Though they occur at several horizons in the upper part (Bernician) of the Carboniferous Limestone Series, they exist in workable quantities only on a few horizons. In the Coal Measures their distribution is more general, but with a greater concentration in the lower part, though not in sufficient quantities to meet the local demands. They occur chiefly as nodules, but a few bands of blackband ironstones, of inferior quality and thickness to those of Scotland and Staffordshire, are met with in the Carboniferous Limestone Series.

Analyses are wanting, but according to Bell the iron produced from the Redesdale bed was "of a very excellent description" (*Rep. Brit. Assoc.* for 1863 (1864), p. 740).

The output has not been systematically returned. That for particular localities is given under their description in the following pages.

As regards reserves, the ores are patchy in distribution and little is known of their varying yield. A conservative estimate would give about 1,500,000 tons for the partially worked areas around Redesdale and Bellingham.

Ironstones in the Carboniferous Limestone Series.

The position of the ironstones that have been worked are shown in the following table:—

	Thickness in feet.
Fell Top Limestone	—
Sandstone and shales	500
Little Limestone	—
Sandstone and shales	50
Great Limestone	—
Blackband ironstone of Chollerton	—
Sandstone and shale	80
Four Fathom Limestone	—
Blackband ironstone of Haydon Bridge—	
Sandstone and shale	100

	Thickness in feet.
Ironstone of Haltwhistle	—
Three Yard Limestone	—
Sandstone and shale	50
Five Yard Limestone	—
Sandstone and shale	50
Scar Limestone	—
Sandstone and shale	120
Tyne Bottom Limestone	—
Sandstone, shale and thin limestones	450
Four Laws Coal	—
Sandstone, shale and Four Laws Limestone (ferruginous)	250
Redesdale Limestone	—
Ironstone of Redesdale and Bellingham	—
Sandstones, shale, thin limestones and coals	1600
Sandstones, shale, conglomerate	2000

The limestones undergo a change of name in different parts of Northumberland. Their correlation is given by Dr. Stanley Smith. (Report upon the Carboniferous Limestone Formation of the North of England, *N. of England Inst. Min. and Mech. Eng.*, 1912, p. 7.)

The Redesdale Ironstone.

From notes by R. L. Sherlock.

The Redesdale Limestone is a persistent band in the Rede Valley and generally rests on a sandstone below which the ironstone-bearing shales occur, but "throughout a great part of the district the nodules are small and light and probably of little value."[1] Around Redesdale Village, Bellingham (Hareshaw), the yield was sufficient to cause rather extensive, though not very profitable workings which, however, have been closed since 1878. The ironstone measures crop out in Hareshaw Burn, where they were got in open-workings and from levels and shafts on Hareshaw Common. The following is the general section below the Limestone according to Mr. T. J. Taylor.[2]

	Ft.	Ins.
Lower Limestone	15	0
Freestone	6	0
Top Shale, with shell-band (6 ins.) and ironstone-nodules	14	0
Bottom Shale, richer in nodules	15	10
Fireclay	4	0
Grey beds	2	10
Freestone	12	0
Grey shale	5	1
Ironstone, Isabella band	0	3
Coal, splint	0	1½
Ironstone, Thomas band	0	10
Coal	0	6
Sandstone and shale	93	0
Coal, Upper Hall Seam	1	3
Sandstone and shale	30	0
Coal, Furnace Seam	1	4

[1] 'The Geology of the country around Otterburn and Elsdon' (*Mem. Geol. Surv.*), 1887, p. 123.

[2] 'An Account of the Strata of Northumberland and Durham,' *Trans. N. of England Inst. Min. Mech. Eng.* Supplementary vol., 1910.

A partial analysis of a perfectly clean sample is quoted by Bell (*op. cit.*, p. 757) as giving: iron, 36·51; lime and magnesia, 11·90; clay, 7·15; loss by heat, 34·07. In furnace-practice the yield was found to be 33 per cent. of iron. Three furnaces were erected at Hareshaw, local coal and limestone being used in smelting, but as the works were nearly 20 miles from a railway and 20 more from a market, the iron cost 12s. per ton for carriage to the consumer (Bell, *op. cit.*, p. 740).

Bell, quoting Mr. Benjamin Thompson, gives a yield of 8,470 tons of ironstone per acre, of which two-sevenths of the whole amount was contained in the lowest 6 feet of strata. The actual production was 5,647 tons per acre.

Statistics of output are not obtainable. Around Redesdale Village the workings extend from near Steel Farm on Broomhope Burn, northwards to the railway, at about $2\frac{1}{4}$ miles N.N.E. of Redesmouth Junction.

The ironstones resemble those of Bellingham, occurring as nodules throughout 30 ft. of shale, of which the lowest 6 feet is richest, underneath a sandstone 6 feet thick which is overlain by the Redesdale Limestone. The ironstone-nodules generally take the form of lenticles, ranging from the size of a pea to masses of 50 lbs. weight.

A partial analysis of a perfectly clean sample gives, according to Bell (*op. cit.*, p. 757), iron, 34·86; lime and magnesia, 9·00; clay, 14·00; loss by heat, 31·02.

The workings, comprising the Broomhope and Steel Royalties, consist of large open quarries extending almost continuously for $1\frac{1}{3}$ miles, measured in a straight line. There is also a large open working about half-a-mile nearer to Redesdale Village forming a third royalty. When the overburden became too thick, pillar-and-stall mining was introduced. As much as three-quarters to four-fifths of the bed was left as pillars.

During the first period of mining the ore was smelted at Redesdale Village, but the furnaces there having been dismantled the ore was sent to Elswick Works. Bell estimated that at Redesdale the cost of ironstone for a ton of iron was 29s. 3d. The Fourlaws Limestone is locally in a ferruginous condition and was at one time put into the furnace along with the Redesdale Ironstone ('Geology of the Country around Otterburn and Elsdon' (*Mem. Geol. Surv.*, 1887, p. 48).

The Mineral Statistics (*Mem. Geol. Survey*), give an output of 20,948 tons in 1871 and 13,889 tons in 1873. For other years no figures are given.

At Haltwhistle and Nenthead "ballstones" were worked at their outcrop in 1856, according to Warington Smyth ("Iron Ores of Great Britain," *Mem. Geol. Survey*, 1856, p. 16), but Bell (*op. cit.*, p. 741) mentions that the works were abandoned soon after their erection. The horizon of the workings at Nenthead is uncertain; they may have been on a weathered outcrop of

spathic ore, but those at Haltwhistle lie directly above the Three Yard Limestone which crops out one mile north of Haltwhistle, where ironstone has been raised at intervals along the outcrop for a distance of four miles to the east.

The neighbourhood of Haydon Bridge is interesting as containing at Chesterwood a blackband ironstone in the Carboniferous Limestone Series. The bed in question lies below the Four Fathom Limestone, between two faults which limit the outcrop on the north and south. It forms a dome. According to Bell (*op. cit.*, p. 733), the stone "in some measure resembled the famous Black-band ironstone of Scotland, containing, however, much more coal than the celebrated ore of this name. It varied, according to Mr. Bigland, who worked it, from 3 to 4 feet in thickness. The raw stone contained 20 to 25 per cent. of iron; but instead of 2 tons of raw material producing 1 ton of calcined, as in the case of Scotland, 3 tons were required . . . for several years they obtained 20,000 to 25,000 tons of raw stone, until the bed was exhausted in that locality in 1855, after less than ten years' working." The bed is apparently a local development, for no mention of an ironstone is made in the numerous shaft-sections penetrating these strata.

A similar local development of a blackband ironstone, in this case below the Great Limestone, occurs one mile south of Chollerton Station, the outcrop extending east and west for about four miles. The ironstone thins away on the east to one inch and appears to be at its maximum thickness near Brunton Limeworks, where the section is: limestone; shale, 3 to 4 ft.; blackband ironstone, 1 ft.; coal, 10 in. (Six-inch Geological map, Northumberland 85 N.W.). Ironstones are occasionally associated with the Little Limestone, occurring both above and below it, at Dryburn Hill, Alston and Middleton-in-Teesdale: but there are no particulars as to their quality or to what extent, if ever, they have been worked.

Ironstones in the Coal Measures.

In the Coal Measures the most systematically worked ironstones are those occurring towards the base of the series in association with the German Bands Coal around Shotley Bridge and Consett. Some ironstone was obtained in getting coal, chiefly in connexion with the Brockwell, Harvey, Hutton, Low Main, Main, and Five Quarters coals. All these ironstones are irregular and impersistent. Ironstones from one or other of these seams were worked on Walridge Fell, Urpeth, Birtley and Bedlington.

At Shotley Bridge the yield is stated by Bell (*op. cit.*) to have been 5,324 tons to the acre, and an analysis of a perfectly clean sample showed; iron, 36·68; lime and magnesia, 4·65; clay 15·05; loss by heat, 31·91.

Yorkshire.

By W. Gibson.

General Account.

This coalfield extends from near the southern banks of the Humber to the Trent south of Nottingham City, and into Derbyshire. The Coal Measures lie in a basin the western part of which alone comes to the surface. In this part the ironstones crop out and are inclined at gentle angles towards the centre of the basin. Ironstone-workings, now mostly disused, occur at intervals along the crop, and a few mines in the north, between Leeds and Bradford, still raise ironstone. Though the local supply of ore is abundant and was used for wrought iron in early days, yet foreign iron was used in Sheffield more than 300 years ago.[1]

Some of the coals (Fig. 2, p. 39) are common to all three counties, but, with one or two exceptions, the ironstones have a local distribution. All, however, occur between the Alton (Halifax Hard or Ganister) Coal and the Top Hard (Barnsley or Warren House) Coal.

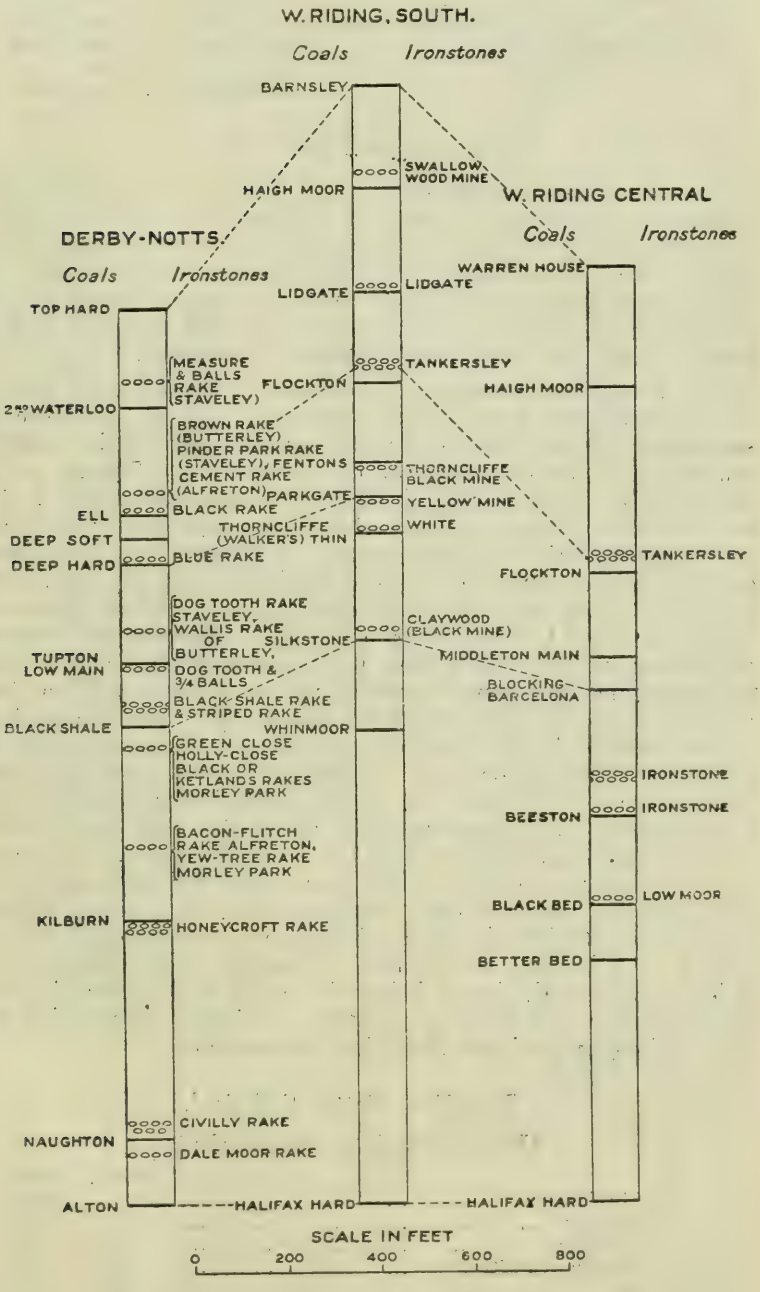
In respect to ironstones the Yorkshire Coal Measures admit of a division into two districts, north and south respectively of the Calder River (figs. 3 and 4). At the present day the working of ironstone is confined to the northern district, south of Bradford. In the southern district the ironstones were chiefly obtained near their outcrop between Rotherham and Barnsley and intermittently farther north. The ironstones, yielding from 1,000 to 3,400 tons per acre with an average yield of 1,500 tons per acre, occur chiefly as nodules, rarely in thin bands, and never in thick beds.

Analyses of individual ores are given on p. 46. All are ferrous carbonates of iron and belong to the clay-ironstone class (p. 1). The metallic iron ranges between 16 and 34 per cent. of the other constituents; the percentage of silica varies most.

The annual output, according to the Returns of the Home Office, has gradually fallen from 175,681 tons in 1882 to 15,592 tons in 1916. Previous to 1882 the Mineral Statistics of the United Kingdom (*Mem. Geol. Survey*) show a fluctuating output between a minimum of 175,000 tons in 1859 and a maximum of 785,628 tons in 1868, of which 617,628 tons was Low Moor Ironstone. Since 1885 the annual output has fallen short of 100,000 tons. Thus the output (293,339 tons) of pig-iron for Yorkshire is far in excess of that of native ore which is raised mainly for use at the Low Moor Ironworks.

[1] Handbook and Guide to British Association Meeting, Sheffield, 1910, p. 210.

FIG. 2.—*Sections illustrating the Ironstones of the Derbyshire, Nottinghamshire, and Yorkshire Coalfields.*



The following estimates of reserves are given for the chief and more persistent ironstones:—

	More or less developed. tons.	Additional Reserves. tons.
Low Moor Ironstone	3,840,000 ...	38,400,000
Claywood and White Mine Ironstone ...	53,760,000 ...	40,320,000
Tankersley Ironstone	35,840,000 ...	25,600,000
	93,440,000 ...	104,320,000

Details of the Ironstones.

Low Moor (Black Bed) Ironstone.—This is the only ironstone at present utilised from the Coal Measures of Yorkshire, and it is raised only in localities where it can be worked in conjunction with the Black Bed Coal. The annual output does not now reach 30,000 tons, but out of 785,620 tons of ironstone raised in 1868 from the Coal Measures of Yorkshire, the bulk is stated to have been "Black Bed Ironstone" (Mineral Statistics).

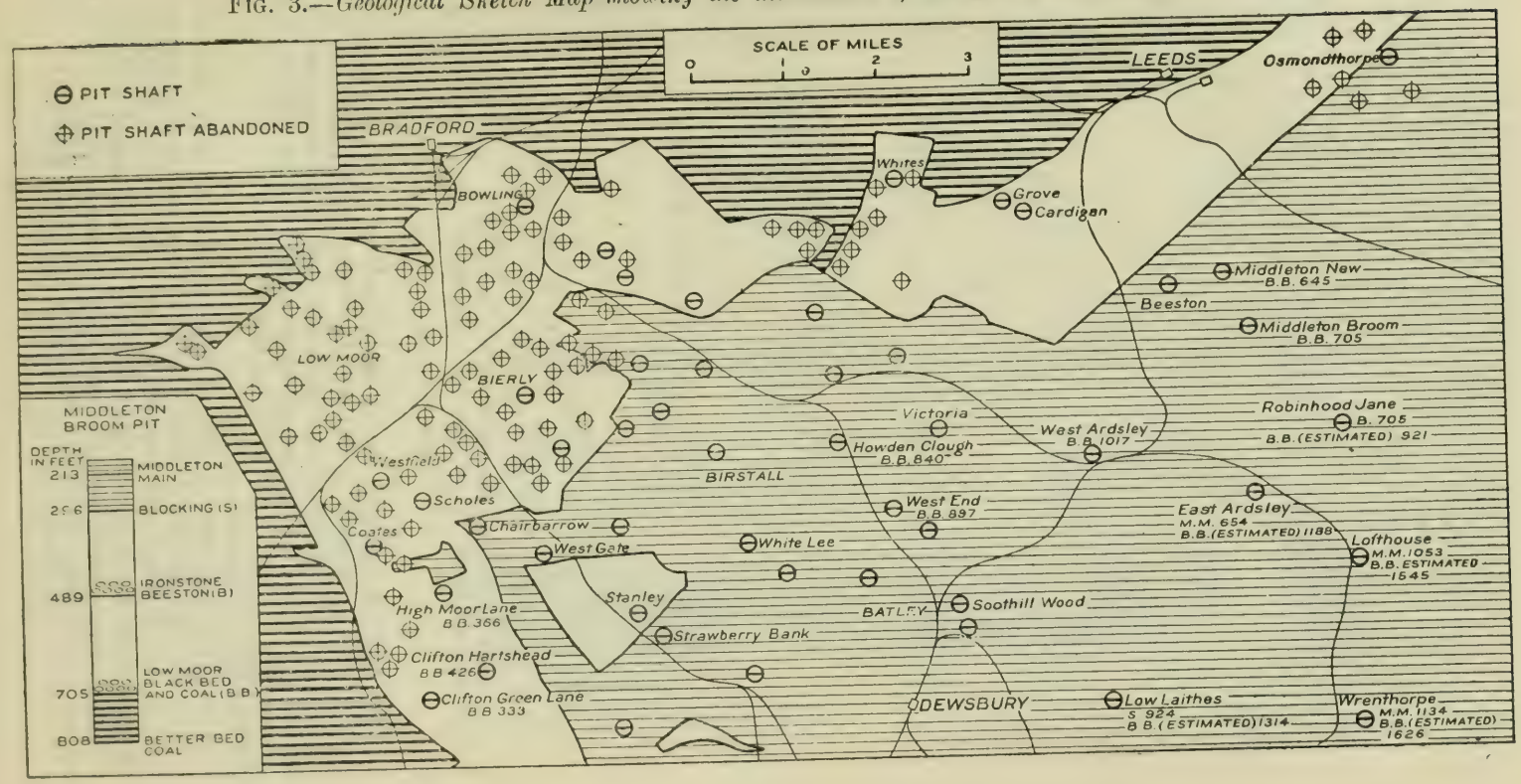
The Black Bed ironstone is confined to the northern part of the coalfield, the shales with ironstones coming on where the sandstones at this horizon in the central part of the coalfield commence to die out north of Gawthorpe. At Clifton, east of Brighouses, the shale with ironstones is separated by 30 feet of barren shales from the Black Bed Coal; but the barren shales gradually diminish northward until at Scholes, two miles north of Clifton, the ironstone measures lie directly on the coal. This position they maintain to their outcrop north of Low Moor and thence eastward to Leeds (Fig. 3, p. 41). Much of the ironstone and much of the Black Bed Coal and the Better Bed Coal, without which the ironstone would not be raised at all, has been exhausted. Since the coke of the Better Bed Coal is considered to be essential in the production of the particular class of iron known as "Low Moor Iron," a few particulars about this seam will not be out of place. It lies 40 yards below the Black Bed Coal, so that the area occupied by the Better Bed Coal is somewhat greater than that in which the ironstone occurs. It may be said to commence as a workable seam about Kirkburton, S.E. of Huddersfield, and to extend slightly beyond the northern outcrop of the Black Bed Coal. The thickness varies between 1 ft. 6 in. and 2 ft. 5 in. and occasionally it reaches 3 ft. The seam is a bituminous coal, dense, bright in colour and remarkably free from sulphur and other impurities. It burns to a white ash. The following analyses show its composition:—

Low Moor Better Bed Coal.

(From Low Moor Ironworks.)

	Hards.	Softs.
Fixed carbon	83.45	84.03
Sulphur	0.41	0.41
Hydrogen	5.35	4.98
Oxygen and nitrogen	7.63	7.11
Ash	1.08	1.75
Moisture	2.08	1.72

FIG. 3.—*Geological Sketch Map showing the distribution of the Low Moor Black Bed Ironstone.*



The ironstones occur in the shale over the Black Bed Coal in thin continuous layers, in bands of nodules or in isolated nodules. The shales vary from 6 ft. to 12 ft. in thickness, separable into two layers according to the quality and character of the ironstones. In the upper layers the ironstones exist as thin bands, but are poor in quality and are not raised; in the lower layers the ironstones occur as nodules, smaller than those usually worked in the Coal Measures and averaging about 3 in. in the longest diameter. In 'N' Pit, Tong, the position of the ironstones is as follows:—

Black Bed Ironstone at N. Pit, Tong.

			Ft.	Ins.
Rock measure			0	1
Light shale			0	6
Ironstone			0	1
Shale			0	7
Ironstone, *Double*			0	1
Shale			1	2
Ironstone			0	1
Shale			0	6½
Ironstone			0	0½
Shale			0	2½
Ironstone			0	0½
Shale			0	8
Ironstone			0	0½
Shale			0	7½
Ironstone			0	0½
Shale			0	4½
Ironstone			0	1
Shale			0	7
Ironstone			0	1
Shale			0	5
Working measures: Ironstone, *Top Balls* ...	White Bed Ironstone		0	0½
Dark shale			0	3
Ironstone, *Rough Measures*			0	0½
Dark Shale			0	5
Ironstone, *Flat Stones*	Black Bed Ironstone		0	3
Dark shale			0	5
Ironstone *Rough Measures*			0	0½
Dark shale			0	7
Ironstone, *Middle Balls*			0	2
Dark shale			0	10
Ironstone, *Low Measures*			0	1
Dark shale			1	2
Black Bed Coal.				

The Middle Balls is the richest band and not only are the ironstones above the Top Balls of inferior quality, but if mixed to any extent with the other ores are said to make an inferior quality of iron. In the upper layers the ironstones (White Bed Ironstone) are of a lighter colour than those in the lower layers (Black Bed Ironstone).

The yield per acre is from 1,000 to 1,200 tons of best ore, which is low compared with the ironstone measures formerly raised in Derbyshire and other parts of Yorkshire (p. 38). Around Low Moor and Burley the ores are exhausted and they are no longer raised at Churwell and Hunslet. They are got chiefly at Wike, Scholes, Osmondthorpe and Beeston; and

incidentally, but in smaller quantities, by collieries working the Black Bed Coal. It is a usual practice to obtain the Black Bed Coal by a first and the ironstone by a second working. Great care is taken that the ore is thoroughly cleaned of adhering shale before it is calcined. The ironstone is spread on the surface of the ground to weather and is repeatedly turned and cleaned. The ore is calcined in a Gjers continuous kiln.

The Low Moor White Bed Mines are clay-ironstones varying in colour from a light brown-grey to black-grey. The upper layers are harder than the lower. The Black Bed Mines are all dark blackish-grey clay-ironstones, compact and hard. Iron pyrites is sometimes present in the form of thin films, occasionally as veins. There is no marked difference in the composition of the two mines except in the proportion of silica, which is higher in the White Bed than in the Black Bed. Analyses by Mr. J. W. Westmorland of samples taken from six pits on the Hunsworth side of the Bowling Colliery give the percentage of metallic iron as 29·15 minimum and 30·79 maximum.[1] It is therefore not a particularly rich ore and in general composition it is not superior to other Yorkshire ores.

The finished Low Moor iron has obtained a world-wide celebrity. Analyses showing the composition of the pig and of the separate grades to the finished iron are appended:—

Analyses of Low Moor Irons.

	Pig iron. A	Pig iron. B	Refined iron. B	Puddled iron. B	Finished iron. B
Combined carbon ...	0·393	0·550	3·100	—	0·081[2]
Graphite	3·361	3·060	—	—	—
Graphitic carbon ...	—	—	0·400	—	—
Carbon	—	—	—	0·420	—
Silicon	1·382	1·335	0·253	0·039	0·104
Sulphur	0·063	0·049	0·038	0·008	trace
Phosphorus	0·602	0·367	0·244	0·240	0·041
Titanium	trace	—	—	—	—
Manganese	1·475	0·808	0·720	—	trace
Arsenic	—	—	—	—	0·008[1]
Iron	92·952	93·831[1]	95·200	99·010	99·766
[100·152]	100·228	100·000	99·955	99·717	100·000

[1] By difference. [2] By colour determination.

(A) Bowling pig-iron, J. Willcock, *Rep. Brit. Assoc.* for 1873, p. 221, Bradford Meeting.
(B) Low Moor Iron Works.

Claywood, Black Shale, or Silkstone Ironstone.—As a workable ironstone this appears to be confined to the southern part of the county, and to have been obtained chiefly in the Sheffield District. It occurs as nodules in shales at an average distance of about 12 yards above the Silkstone Coal. At the bottom of the ironstone measures there lies a thin coal, remarkably persistent throughout the coalfield, which is mentioned in most pit-sections from those near the county border south of Sheffield to those near the outcrop south of Leeds. But in the records relating to the central and northern regions no mention is made of ironstones in the shales above this thin coal.

[1] 'Geology of the Yorkshire Coalfield,' *Mem. Geol. Surv.*, 1878, p. 155.

The ironstone occurs in several courses, to which names were capriciously and not systematically given. At Strafford Main Colliery the terms 'White Ironstone Mine' and 'Black Ironstone Mine' were applied to two layers, though they were used also for ironstones much higher in the sequence. A considerable quantity of ore was obtained between 1850 and 1870 to the west of Kimberworth and between Grange Lane and Chapeltown north of Sheffield.[1]

In the 'Iron Ores of Gt. Britain' (p. 75) the stone is described as a "dark greyish-black clay-ironstone, having some very small particles of pyrites sparingly diffused through it. Tolerably hard; the surface of fracture minutely granular." It is stated to yield 1,500 to 1,600 tons per acre.

White Mine Ironstone.—A seam of coal (Walkers Thin, Thorncliffe Thin, Thorncliffe Muck, Middleton Little or Hard Band Coal), from 150 to 200 ft. above the Silkstone Coal extends throughout the coalfield. In the southern part of the district between Holmes and Silkstone, shales including ironstones known as the White Mine Ironstone, rest on the coal. The ironstones were obtained at Holmes, and near Thorpe Healey. An outcrop occurs near Chapeltown Station. Locally, ironstone-measures (Yellow Mine) are recorded as occurring immediately below the Park Gate Coal. About 1,500 tons per acre is given by W. Smyth (*op. cit.*) as the yield of the White Mine measures.

Thorncliffe Black Mine Ironstone.—A strong rock rests on the Park Gate Coal in the immediate neighbourhood of Sheffield, but northwards as the rock thins away shales take its place, and locally, between Greasborough and Silkstone, the Black Mine Ironstone measures, yielding about 1,500 tons per acre, make their appearance.

Tankersley Ironstone.—At a distance of 10 to 25 ft. above the Flockton (Hewards or Adwalton Stone) Coal, ironstones, lying in shales are somewhat generally distributed over the Yorkshire Coalfield. The occurrence of ironstone at this horizon is mentioned in many but not all shaft-sections, and the ore has been worked at intervals from near Sheffield as far north as Ardsley, four miles south of Leeds. It was extensively worked round Greasborough, Tankersley, Pilley and Cawthorne, by shallow pits, the shale heaps still remaining. About 12 to 15 in. of ironstone, in three courses, occur in about 6 ft. of shale. The yield ('Iron Ores of Great Britain,' p. 36) is stated to have been from 2,000 to 3,400 tons per acre. No published analyses appear to be in existence, but as the stone contains numerous fossil shells the lime percentage is probably high. At West Ardsley 'the total thickness of ironstone varies from $6\frac{1}{2}$ in. to 8 in., producing about 8 cwt. of ironstone to the square yard, and yielding from 16 to 27 per cent. of metallic iron' (Yorkshire Coalfield, *Mem. Geol. Surv.*, 1878, p. 325).

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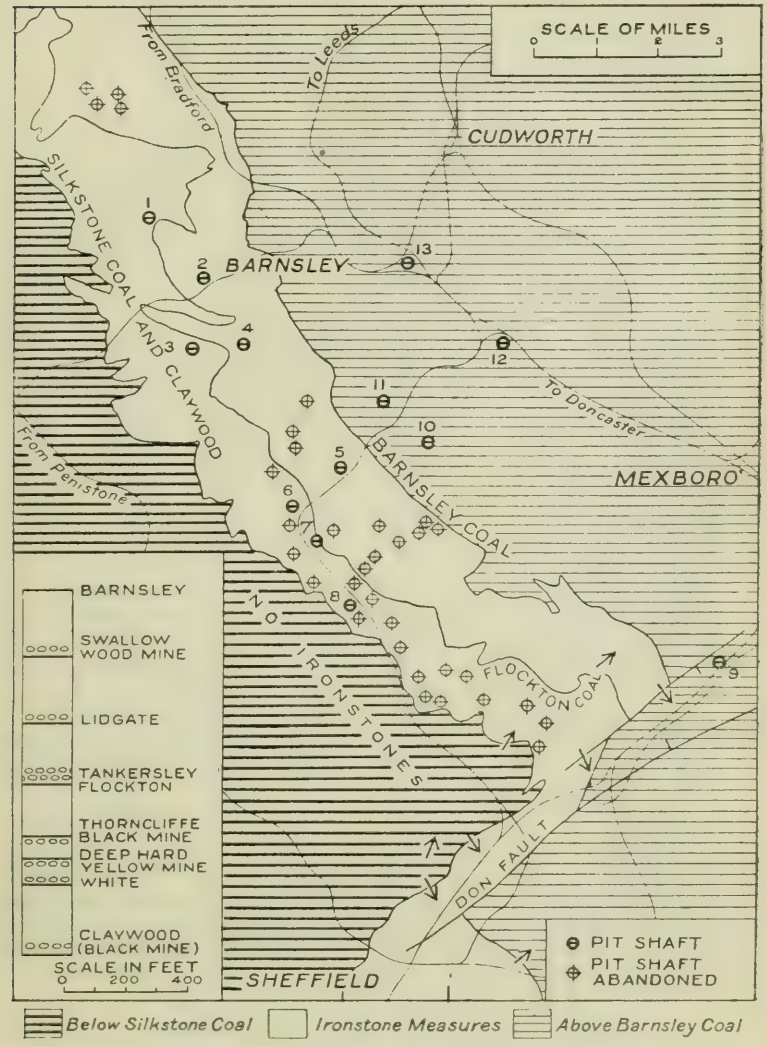
[1] 'Geology of the Yorkshire Coalfield,' *Mem. Geol. Surv.*, 1878, pp. 248–250. Several sections are also given of the ironstone measures.

FIG. 4.—*Geological Sketch-map, illustrating the Ironstone Measures near Sheffield and Barnsley.*



1. Stanhope Silkstone Colliery.
2. Church Lane.
3. New Sovereign.
4. Strafford Main.
5. Rockingham.
6. Wharncliffe Silkstone.
7. Tankersley.
8. Thorncliffe.
9. Roundwood.
10. Hoyland Silkstone.
11. Barrow.
12. Mitchells Main.
13. Barnsley Main.

The sections of the ironstone measures towards the southern part of their outcrop at working coal-pits are:—*Strafford:* Tankersley Ironstone, 4 ft. 1 in.; bind with ironstone, 13 ft. 1 in.; Flockton Coal. *Barnsley Main:* Dark bind with ironstone bands, 21 ft. 3 in.; Flockton Thick Coal. *Barrow:* Tankersley Ironstone, 13 ft. 3 in.; measures, 9 ft. 8 in.; Flockton Thick Coal. *Rockingham:* Tankersley Park Mine, 7 ft. 8 in.

Lidgate and Swallow Wood Ironstones.—Neither of these ironstones was of much consequence. The Lidgate bed was rarely worked and the Swallow Wood Ironstone chiefly in Tankersley Park. The Swallow Wood Coal is generally known as the Haigh Moor and is regarded as the first valuable coal of any persistence below the Barnsley Coal.

Analyses of Ironstones, Yorkshire.

('Iron Ores of Great Britain,' Pt. I., *Mem. Geol. Surv.*, 1856, pp. 66-76.)

	(1)	(2)	(3)	(4)	(5)
Ferrous oxide	35·38	36·14	39·87	39·38	41·77
Ferric oxide	1·20	0·61	0·53	1·24	1·96
Manganous oxide	0·94	1·38	1·38	0·95	1·13
Alumina	0·80	0·52	0·74	0·82	0·58
Lime	2·78	2·70	2·12	2·26	2·55
Magnesia	2·22	2·05	2·64	3·72	3·71
Carbon dioxide	25·41	26·57	28·47	29·38	31·39
Phosphoric acid	0·48	0·34	0·69	0·47	0·75
Sulphuric acid	trace	trace	trace	trace	trace
Iron pyrites	0·18	0·10	0·05	trace	trace
Barium sulphate	—	—	—	trace	—
Water at 100° C.	0·74	0·61	0·59	0·68	0·55
Water combined	1·11	1·16	1·21	1·41	1·15
Organic matter	0·23	2·40	0·83	0·54	0·86
Ignited insoluble residue	28·00	25·27	20·30	19·35	14·16
	99·47	99·85	99·42	100·20	100·56
Ignited insoluble residue—					
Silica	19·73	17·37	13·50	12·16	8·93
Alumina	6·83	6·22	5·39	5·60	4·21
Ferric oxide	0·57	0·84	0·77	0·45	0·43
Lime	0·11	trace	trace	trace	trace
Magnesia	0·07	0·12	0·13	0·17	0·14
Potash	0·78	0·65	0·18	0·37	0·43
Metallic iron	28·76	29·12	31·92	31·82	34·16

(1) Low Moor, White Bed Mine, Bierley. (2) Low Moor Black Bed Mine, Bierley. (3) Black or Clay Wood Mine, Parkgate. (4) Thorncliffe White Mine, Parkgate. (5) Thorncliffe or Old Black Mine, Parkgate.

Derbyshire and Nottinghamshire

By W. Gibson.

General Account.

Derbyshire and the parts of Nottinghamshire bordering the Derbyshire Coalfield, have long been a centre of an active iron industry founded on the local abundance of ironstone and coal. The iron-manufacturing centres remain, but no longer draw their supplies of raw material from the local ores. The annual output has never quite scaled 500,000 tons. Up to 1873 it lay between 300,000 and 400,000 tons, but since 1873 it has rapidly fallen off until it has now reached the point of extinction.

The geological structure is much the same as in Yorkshire, with Coal Measures inclined eastward off the Millstone Grits,

the angle of inclination gradually decreasing to the east. Most of the ironstones, and all of those that were formerly worked on a considerable scale, crop out along the western margin or basset edges of the coalfield, and again rise up to the surface towards the centre of the visible coalfield in the locally developed anticlines of Norton and Brimington (Fig. 5, p. 50), or within easy reach of the surface in the Riddings anticline. A broad, and in some cases a duplicated outcrop of ironstone measures results.

The Lower and Middle Coal Measures are represented, the Silkstone (Black Shale or Clod) Coal forming the line of separation between the two sub-divisions. Ironstones occur throughout, but are chiefly developed near the bottom of the Lower Coal Measures and towards the bottom of the Middle Coal Measures (Fig. 2, p. 39). They usually take the form of nodules, scattered irregularly through a matrix of shales or of definite layers termed 'rakes.' Occasionally they are found in bands of a few inches in thickness.

The reserves of the chief and persistently developed ironstones are as follows[1]:—

	More or less developed. tons.		Additional reserves. tons.
Dale Moor and Civilly Rakes	8,960,000	...	13,440,000
Honeycroft Rakes	38,400,000	...	—
Black Shale and Striped Rakes	304,000,000	...	—
Brown Bakes...	115,200,000	...	—
	466.560,000	...	13,440,000
Total	480,000,000 tons.		

A conservative estimate of one hundred million tons can be made for locally distributed ironstones.

Details of the Ironstones.

Dale Moor and Civilly Rakes.—These ironstones, obtained by opencast to the north-east and north of Stanton-by-Dale and to the west and north of Dale, are the lowest ironstones ever worked in any of the Midland coalfields. They have not been worked elsewhere in Derbyshire, and except in the southern end of the coalfield no coal-pits have been sunk to this horizon, none of the coals below the Kilburn Coal being of commercial value.

Before the introduction of the Mesozoic ores the Stanton Ironworks were mainly supplied with these local ores.

The Dale Moor Rakes lie below and the Civilly Rakes above a thin seam of coal known as the Naughton Coal which lies 130 ft. above the Alton Coal and 850 ft. below the Black Shale or Silkstone Coal.

The Dale Moor Rake occurring in five courses of nodules amidst 20 ft. of shale yields about 3,000 tons per acre. Fossils, both plant and animal, are abundant, and on this account the ore is somewhat richer in phosphorus than other Derbyshire ironstones. The Civilly Rake lies in five courses of nodules in 60 ft. of shale and yields about 4,000 tons per acre.

[1] The estimated yield per acre of the different ironstones is that given in the 'Iron Ores of Great Britain,' *Mem. Geol. Surv.*, Pt. I., 1856, pp. 37-39.

Honeycroft Rake.—Somewhat more prolific than the Dale Moor Rake and Civilly Rake the shales containing these ironstones were worked by opencast in the Dale district, and thence, at intervals northward to Ambergate.

The ironstone measures lie almost immediately below the extensively worked Kilburn Coal. About eight courses of ironstone balls and cakes lying amidst 45 ft. of shale and yielding 6,000 tons per acre form the productive zone. Fossil shells and fish remains are fairly common in some of the ironstone balls. The Kilburn Coal is essentially a South Derbyshire Seam, nor is there any information that the ironstone occurs over the central and northern areas where the Kilburn Coal is too thin to be worth getting.

Yew-tree Rake, Baconflitch Rake, Black or Ketlands Rake, Hollyclose Rake, Greenclose Rake.—These ironstones lying between the Kilburn Coal and Black Shale Coal were locally worked in the districts of Alfreton and Morley Park. There is no information to be obtained as to the yield per acre or their iron-contents.

Black Shale Rake.—Most of the ironstone measures hitherto described, being irregularly distributed and of local development, were worked in widely scattered areas, but those in the measures above the Black Shale (Silkstone) Coal afford a remarkable exception, since they extend as a payable group from near Thorncliffe 6 miles north of Sheffield to Ripley, 9 miles north of Derby, a total distance of nearly 30 miles.

In Derbyshire these ironstone-measures are at their fullest development between Dronfield and Clay Cross, and were extensively worked by opencast, bell-pits, and shallow shafts, west and east of Chesterfield. At the Hady, east of Chesterfield, the rows of nodules are concentrated within two bands of shale called the 'Top Rake' and 'Bottom Rake,' separated by 12 ft. of unproductive shale, the separate rows being named as follows[1]:—

	Ft.	Ins.
Top Rake 15 ft. 11½ ins: —		
'Whetstone,' lean or poor measure, not got	0	1
Shale	1	6
'Single balls,' lean	0	0½
Shale	1	6
'Double Chitter,' lean, brown, rough nodules	0	2
Shale	3	0
'Cheeses,' good measure	0	1½
Shale	2	0
'Bearstone,' capped with cone-in-cone, lean, rough texture	0	1
Shale	2	3
'Blues,' upper, good and rich, flat nodules	0	1
Shale	1	3
'Blue,' lower	0	1½
Shale	2	0
'Old Man,' good, nodules often thick	0	2
Shale	1	6
'Old Woman,' or sheeting, good, flat nodules	0	1
Shale	12	0

[1] 'The Geology of the northern part of the Derbyshire Coalfield and Bordering Tracts,' *Mem. Geol. Surv.*, 1913, p. 116.

Bottom Rake 21 ft. 4½ ins.:—	Ft.	Ins.
Smooth 'Chitter,' a lean measure, brown and rough	0	2½
Shale	3	6
'Flampard,' a very rough, granular structured stone, lean ...	0	3
Shale	2	0
'Red Measure,' good, cleavage planes with white coating ...	0	1½
Shale	3	0
'Chance Measure,' lean	0	0½
Shale	1	6
'Dun-lining,' lean, black with small crystal of pyrites... ...	0	1
Shale	1	0
'Dun Measure,' good, thick black nodules	0	2
Shale	2	0
'Over Lumps,' good, cracks coated with white powder ...	0	1
Shale	1	0
'Nether Lumps,' good cracks coated with white powder, ...	0	1
Shale	1	6
'Overbottoms,' good	0	1½
Shale	1	6
'Roof Measure,' good, rough and black	0	1½
Shale	1	6
'Bottom Measure,' good	0	1
Shale	1	6
Coal smut 2 ft. 3 ins. above the Roof Coal [Silkstone].		

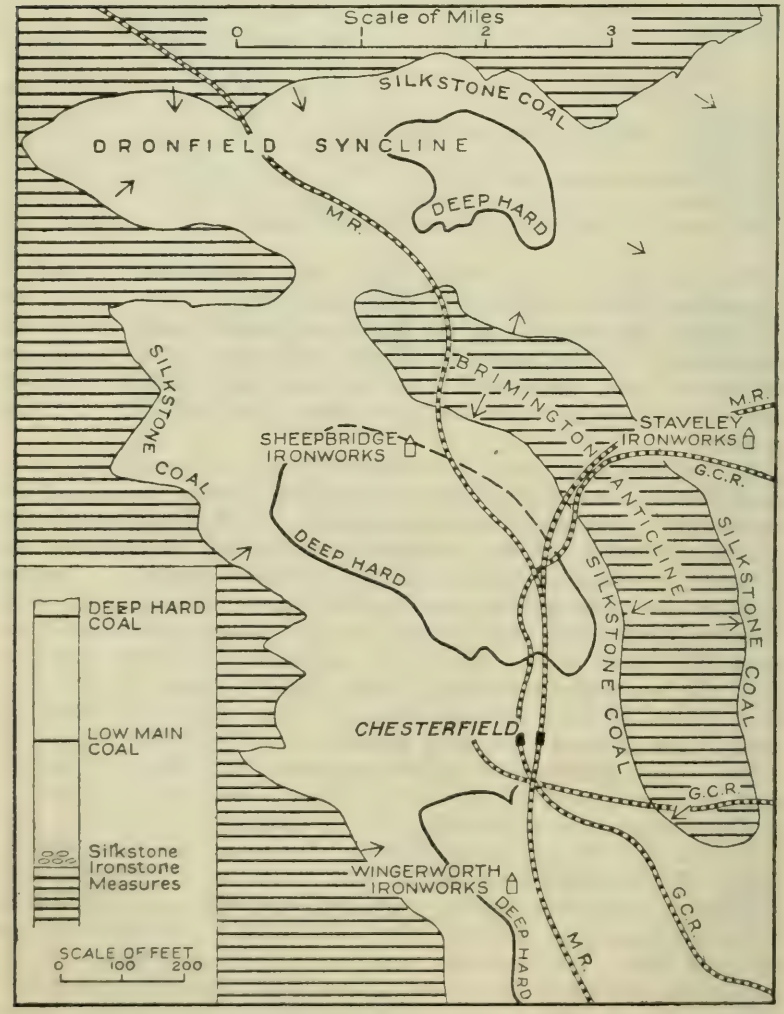
Describing the ores when they were extensively raised to supply the Staveley furnaces, Warington Smyth states that "the 'Cheeses' are remarkable for the symmetrical cracks caused by contraction in the interior. These are mostly filled with carbonate of lime, containing some iron and magnesia, and, where an open space has been left, crystals of zinc-blende are also present.

"The 'Old Man' and 'Old Woman,' grey stones of very compact texture, and with a fracture tending to conchoidal, exhibit numerous cracks of the same description, which, besides a similar mixed carbonate, present abundant crystals of zinc-blende, and isolated crystals of galena in well-defined crystals. Copper-pyrites and iron-pyrites also occur occasionally in the same manner, sometimes even in the partial hollows left around the cast of a fossil shell. The lower ironstones are first extracted and the waste shale or bind, being thrown under foot, suffices so to raise the floor that the men are kept continually near the roof of the upward advancing excavation. Upon this system the upper range of measures is first extracted; and when the ground has sufficiently settled, the lower range is commenced upon."—('Iron Ores of Great Britain,' *Mem. Geol. Surv.*, 1856, p. 43.)

In the districts of Chesterfield and Unstone (Fig. 5, p. 50) the Black Shale Rakes crop out on both flanks of an anticline and thus afford abundant reserves, at shallow depths and situated in close proximity to railroads, for the Staveley and Sheepbridge Iron Works. The ores also are not inferior in richness to the imported ores from Cleveland, Lincolnshire and Northamptonshire. Yet, at the present time these local ores are not drawn upon. This is a striking instance of a complete change of practice in an important industry brought about by new conditions of trade manufacture. The Black Shale Rakes were also worked near or at their outcrop by the Staveley Company, on the eastern side of the anticline (Brimington anticline) near Ringwood. West of

Chesterfield, the Silkstone Coal and associated ironstones, were obtained along nearly the whole course of their outcrop as far south as Clay Cross. In the records of the sinkings of the Clay Cross Colliery between the Avenue Pit in the north near Wingerworth and the Morton Pits in the south near Doehill Station the measures named the Black Shale Ironstone range from 63 to as much as 96 ft. above the Silkstone Coal.

FIG. 5.—*Sketch-map of the Silkstone Ironstone Measures around Chesterfield.*



South of Butterley the Black Shale ironstone-measures are of small account. Around Butterley the ironstones are found at a distance of 12 yards above the Clod (Black Shale) Coal. According to Warington Smyth the yield is between 4,000 and 7,000 tons per acre.

Dog-tooth Rake and Three Quarters Balls.—Of the ironstones above the Black Shale Rake, though some were of local importance, only the Brown Mine Ironstone above the Ell Coal has a general distribution in the Derbyshire Coalfield.

The Three Quarters Balls, below the Tupton Coal, formed a very productive working at Clay Cross. It is probably the same bed known as the Nodule Rake of Morley Park and Dog-tooth Rake of Butterley, though the latter name was more generally applied to an ironstone occurring above the Tupton Coal.

The Three Quarters Coal of Clay Cross is an excellent seam and the ironstones immediately above it were at one time worked with the coal. At No. 2 Clay Cross Colliery the Three Quarters Coal, at a depth of 74 yds. is immediately overlain by the ironstones which lie in five courses, similar ironstones being recorded in the other pits of this company, but at No. 1 Black Shale Pit the ironstone-measures lie 17 ft. above the coal. Around Butterley Park the pit-sections also record ironstone in four courses lying directly on the representative of the Three Quarters Coal. Further south in the Ilkeston District, three thin courses of ironstone lying in clunch occur above the Three Quarter Coal, which is 2 ft. 5 in. thick at the Manners Colliery.

The Dog-tooth Rake of the Chesterfield district is mentioned by Smyth (*op. cit.*, p. 40) as one of the most important in the field and is stated to have yielded 2,000 tons per acre. It lies about 40 ft. above the Tupton Coal. Wallis' Rake of the Butterley District is on or near the same horizon.

Brown Rake, Pinder Park Rake, Buff or Cement Rake.—Nodules and layers of ironstone in shales and clunches commonly occur between 30 to 60 ft. above the Deep Soft Coal throughout the county, and in Yorkshire the Tankersley ironstone-measures (p. 44) appear at about the same horizon. Between the Tupton Coal and the Deep Soft Coal, ironstones are found irregularly on several horizons, but there is much confusion in their nomenclature as it was the practice of the miners to give the same name to any ironstones of similar character. Among such names those of Brown Rake, Black Rake, Blue Rake, Whetstone Rake, Old Man's Rake, Riddings Rake occur. None of these ores appear to have been of much importance, but they are interesting as showing the prevalent deposition of ironstone during this part of the Middle Coal Measures in Derbyshire.

The bed to which the name Brown Rake Ironstone is here applied lies above a coal, sometimes of workable thickness, which lies above the Deep Soft Coal and is known as the Ell Coal. In the Staveley district it was known as the Pinder Park Rake, and was extensively worked by the Renishaw Ironworks in a series of bell-pits west of Renishaw Park collieries. The Deep Soft Coal is here known as the Handley Wood and Eckington Deep Soft Coal and the Ell Coal appears to be represented by the Chavery Coal, 90 ft. above which the Pinder Park Ironstones are found. At the Morton Colliery, Clay Cross, it is called the Black Rake Ironstone Rake and is 11 yards above the Ell Coal.

Inkersall Rakes.—Although ironstones are found above the Top Hard Coal they were not generally worked, and in the numerous sinkings to the Top Hard Coal of Nottinghamshire little attention is paid to such ironstones beyond the notification of their occurrence. In the Staveley district and at Duckmanton, three miles east of Chesterfield, ironstones known as the Measures and Balls and Inkersall Rake were used locally but not to any considerable extent.

Analyses of Ironstones, Derbyshire.

('Iron Ores of Great Britain,' Pt. 1, *Mem. Geol. Surv.*, 1856, pp. 79-95.)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ferrous oxide	37·99	35·74	33·56	38·97	28·27	40·01	33·31	39·55
Ferric oxide	1·04	1·26	1·66	0·88	1·01	1·60	1·47	2·71
Manganous oxide ...	1·51	1·23	0·96	1·09	1·02	1·26	2·18	1·50
Alumina	0·41	0·47	0·73	0·38	0·33	0·58	0·95	1·14
Lime	4·53	2·94	3·02	1·58	13·94	2·78	2·32	3·32
Magnesia	3·30	2·70	2·81	4·62	9·18	2·88	2·44	2·85
Carbon dioxide ...	29·92	26·74	25·63	30·14	37·61	29·72	24·83	28·63
Phosphoric acid ...	0·80	0·66	0·79	0·48	0·74	0·34	0·62	1·12
Sulphuric acid ...	trace	trace	trace	trace	trace	trace	nil	trace
Iron pyrites	0·06	0·05	00·26	0·05	0·04	0·09	0·13	0·05
Barium sulphate ...	—	—	—	—	—	—	trace	—
Water at 100° C. ...	0·74	0·68	0·74	0·64	0·18	0·45	0·70	0·51
Water, combined ...	1·47	1·49	1·51	1·02	0·73	1·12	1·87	1·24
Organic matter ...	1·42	0·76	1·57	0·30	0·92	1·38	1·85	1·14
Ignited insoluble residue	16·35	24·83	26·46	19·10	6·39	17·84	27·42	15·80
	99·54	99·56	99·70	99·25	100·36	100·05	100·09	99·56
Ignited insoluble residue								
Silica	10·04	16·07	17·13	11·90	3·55	11·19	17·24	10·22
Alumina	5·16	6·62	7·76	5·55	1·98	5·33	7·90	4·51
Ferric oxide ...	0·45	0·92	0·50	0·59	0·41	0·70	1·22	0·78
Lime	0·06	0·07	0·15	0·04	trace	trace	nil	0·06
Magnesia	0·07	0·26	0·25	0·20	0·09	0·17	0·27	0·03
Potash	0·55	0·66	0·74	0·67	0·16	0·34	0·49	0·48
Metallic iron	30·60	29·32	27·61	31·34	22·98	32·73	27·79	33·20

(1) Brown Rake, Butterley. (2) Brown Rake, Butterley. (3) Black Rake, Butterley. (4) Dog-tooth Rake, Staveley. (5) Dog-tooth Rake, Staveley. (6) Honeycroft Rake, Stanton. (7) Civilly Rake, Stanton. (8) Dale Moor Rake, Stanton.

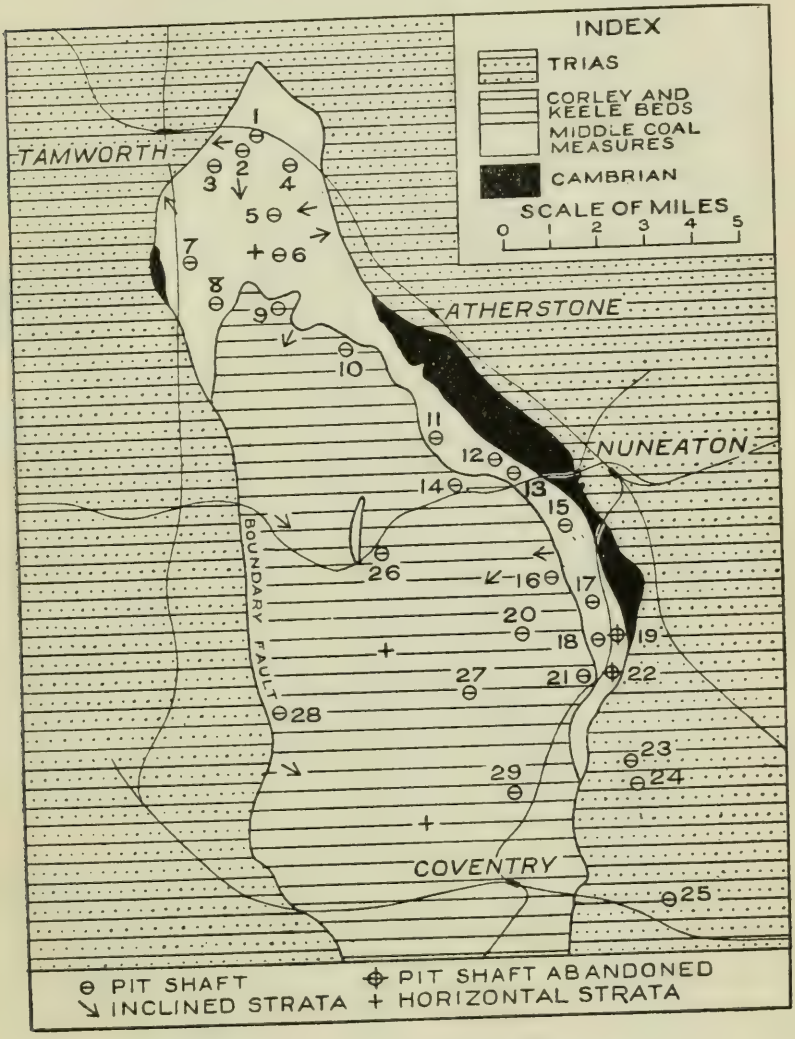
Warwickshire.

By W. Gibson.

GENERAL ACCOUNT.

Though the Coal Measures were a source of ironstone at an early period, no modern furnaces have been built in the coalfield, and the ores were and are still sent to the furnaces of South Staffordshire and Shropshire. Beyond a few casual references the literature of the Warwickshire ironstones is scanty. The Proved Coalfield embraces an area of nearly 130 sq. miles; but

FIG. 6.—*Geological Sketch-map showing the Ironstone Measures of the Warwickshire Coalfield.*



1. Tamworth Colliery.
2. Amington Colliery.
3. Glascote Colliery.
4. Pooley Hall.
5. Birch Coppice.
6. Hallend.
7. Hockley Hall.
8. Kingsbury.
9. Woodend.
10. Baddesley.
11. Ansley Hall.
12. Stockingford.
13. Haunchwood.
14. Haunchwood Tunnel Pits.
15. Griff No. 4.
16. Griff, Clara Pit.
17. Charity.
18. Hawkesbury.
19. Coal Pit Field.
20. Newdigate.
21. Exhall.
22. Grants Farm.
23. Wyken.
24. Craven.
25. Binley.
26. Arley.
27. Coventry.
28. Packington Boring.
29. Whitmore Boring.

only 24 sq. miles belong to the Visible Coalfield, the remaining part being concealed under the so-called Permian. The Coal Measures lie in a broad syncline. Along the eastern and north-western edges the strata turn up sharply, but they rapidly flatten out towards the centre of the basin near the Coventry Pits of the Warwickshire Coal Company (Fig. 6, p. 53). Both the Middle and Upper Coal Measures (including the lower 900 ft. of the so-called Permian) are present, but the ironstones occur only in the Middle Measures which show a gradual diminution from over 700 ft. in the north-west, near Tamworth, to under 500 ft. in the south-east, near Coventry.

In respect to the Seven-feet Coal, which is the only seam continuous over the district, the ironstones are distributed at irregular intervals from 150 ft. above this coal down to the bottom of the Middle Coal Measures (Fig. 7, p. 55). They occur chiefly as nodules, rarely in bands, and then only a few inches thick. The nodules vary greatly in size, but are commonly from 3 to 6 in. in diameter. Some nodules, commonly called cakes, weigh several hundredweight, but these in most cases are made of aggregations of several smaller nodules. The White Ironstone, from 20 to 60 ft. above the Seven-feet Coal, usually occurs in three bands, each from 2 to 3 in. thick. Complete analyses of any of the ironstones are wanting, and of several no analyses are procurable. Partial analyses of the White Ironstone of the Tamworth and Nuneaton districts, as supplied by Messrs. M. and W. Grazebrook, give: Metallic iron, 27 to 40 per cent.; silica, 9 to 13; alumina, 7 per cent. Both sulphur and phosphorus are low, and the ores are poor in manganese.

Between 1856 and 1873 the annual output of ironstone ranged between 15,000 and 50,000 tons. In 1874-75 it reached a maximum of nearly 100,000 tons, followed by a rapid though fluctuating falling off to 91 tons in 1902. A slight revival commenced in 1912, but it has never scaled 8,000 tons.

The yield per acre, except for limited areas, is unobtainable in the Visible Coalfield, and in the Concealed Coalfield little attention has been paid to the records of ironstones recorded in the few borings and sinkings that have reached the Middle Coal Measures beneath the so-called Permian. With the exception of the White Ironstone, the other ironstones are capricious in their occurrence. No reliable estimate of reserves are possible therefore for much of the area under the Permian. The bulk of the ore undoubtedly remains and is large; but the opinion that the ores are better in quality and are more accessible than in other Midland coalfields is incorrect.

The reserves of the White Ironstone can be taken as about 4,608,000 tons, which is the amount given in the table, p. 2.

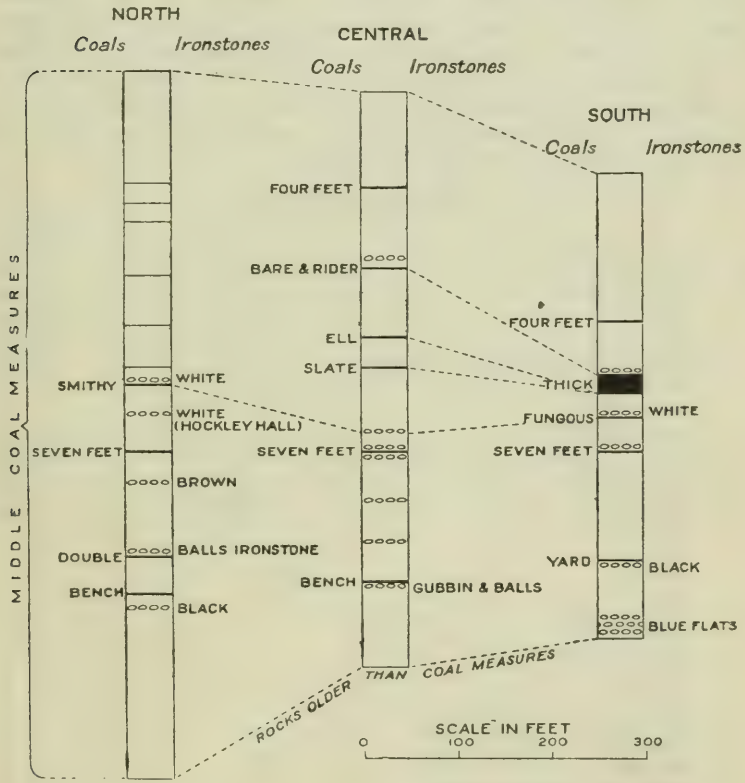
Details of the Ironstones.

From notes by T. Eastwood.

Blue Flats.—These ironstones occur as nodules and thin bands towards the bottom of the Middle Coal Measures in the south-eastern part of the district, but are absent in the northern part of the coalfield.

At the disused pits of Grant's Farm, south of Bedworth Hill, the Blue Flats ironstone-measures, lying 300 ft. from the surface, consist in descending order of: ironstone, 4 to 6 in.; shale with ironstone balls, 4 ft. 2 in.; ironstone, $2\frac{1}{2}$ in. They are more fully developed in the Charity Colliery, Bedworth, where six courses, giving a total thickness of 16 inches of ironstone, lie in 12 ft. of shale. The position of these and other ironstones of this colliery are given in the section (below), illustrating the southern part of the coalfield. In the Hawkesbury New Winning Pit the Blue Flats consist of ironstone, 3 in.; blue bind, 3 ft.; scud and ironstone balls, 9 in. At the Speedwell and New Pits of the same colliery the ironstone measures are made up of:— top stone, 3 in.; blue clod, 2 ft.; middle stone, 0·1 in.; blue clod 2 ft. 2 in.; bottom stone, 4 in.

FIG. 7.—*Sections illustrating the Ironstones of the Warwickshire Coalfield.*



Black Ironstone.—In the southern part of the coalfield (Fig. 7, above) this ironstone was of some importance. It is probably the measure described in the Catalogue of the Great Exhibition of 1851, Part I, p. 153, as the Bedworth Balls. It is there stated to occur in two courses forming an exeedingly good and important measure of ironstone, raised extensively for transport

to the South Staffordshire Coalfield. It was worked at Grant's Farm Pits at a depth of 240 ft. from the surface; and measures, bearing the same name, with 7 in. of ironstone below it are given in the record of the Charity Colliery as occurring 6 ft. below the Yard Coal. Measures with ironstone balls, 2 ft. thick, are also mentioned at the Hawkesbury New Winning Pit, 111 ft. below the Seven-feet Coal. It is said to yield 9 cwt. per square yard and to give 40 per cent. metallic iron. Further north, at Wilnecote Colliery, ironstone balls, called Black Ironstone, appear to represent either this stone or the Gubbin and Balls Ironstone.

Gubbin and Balls Ironstone.—Near Nuneaton a coal known as the Bench Coal appears on or about the same horizon as the Yard Coal of the Charity Colliery. From 5 to 30 ft. beneath it, large balls of ironstone, termed the Gubbin and Balls, are frequently developed. At the Clod Clay Pit of Messrs. Stanley the Bench Coal rests on 10 ft. of white clay containing ironstone nodules which are picked out and laid aside; but no systematic attempt is made to work the ironstones. At the Stockingford Colliery the Gubbin and Balls Ironstone is persistently developed, as well as other ball ironstone-measures from immediately above the Seven-feet Coal and the Bench Coal. The following section obtained in driving from the Bench Coal to the Seven-feet Coal gives the positions of these ironstones.

Stockingford Colliery.

	Ft.	Ins.
Seven-feet Coal	7	0
Fireclay	5	0
Batty coal	0	8
Fireclay	2	9
Batty coal	0	7
Strong fireclay and *balls ironstone*	5	0
Rocky binds	8	0
Coal	2	6
Lamb and batt	1	6
Coal	2	6
Rocky binds	4	8
Fireclay Coal	5	10
Rocky binds	7	3
Batt	0	8
Fireclay	2	0
Coal	2	6
Balls Ironstone	9	0
Five-feet Coal	5	6
Balls Ironstone	6	0
Fireclay	15	5
Coal	2	9
Fireclay	4	0
Bench Coal	5	0
Fireclay	4	3
Gubbin and Balls Ironstone	4	6

Large irregular cakes of ironstone are obtained from above the Seven-feet Coal, and balls of irregular size in working the Fireclay and Five-feet Coals. They are allowed to weather at the surface before they are sent by rail into South Staffordshire. The Gubbin and Balls Ironstone yields 44 per cent. metallic iron in the raw state, according to Mr. W. Hill, the manager.

At the Haunchwood Colliery the Gubbin and Ball Ironstone, consisting of balls and cakes, lies 30 ft. below the Bench Coal. Measures with ball-ironstone occur below the Bench Coal at Baddesley and at other places in the northern part of the coalfield, where also ball ironstones (known as the Brown Ironstone) are occasionally met with between 10 to 20 ft. below the Seven-feet Coal.

White Ironstone.—This is the best known ironstone of the coalfield and is the chief stone raised at the present day and in the past. It is probably the ironstone obtained by open cast at Monks Wood, south-east of Baddesley Common, and smelted by charcoal on the spot, though Howell ('Geology of the Warwickshire Coalfield,' *Mem. Geol. Surv.* 1859, p. 17) suggests that the ironstone there used came from a lower horizon.

The ironstone, occurring in the form of balls and thin bands, lies over a thin seam of coal, known as the Smithy Coal in the north and the Fungous or Stinking Coal elsewhere in the coalfield, but the identification of this coal is based solely on its being the seam next above the Seven-feet, the distance between the two varying between 20 and 60 feet.

At Wyken Colliery the ironstone measures consist of:—top-stone 6 in.; White Ironstone measures 4 ft. 6 in.; bottom stone 4 in.; at Charity Colliery:—top balls 8 in., binds 3 ft.; middle stone 4 in., binds 2 ft.; bottom stone 6 in.; at Hawkesbury Gin Stables Pit:—ironstone balls 1 ft.; binds 1 ft. 8 in.; middle stone 10½ in.; binds 2 ft. 1 in.; bottom stone 5 in.

In the northern part of the coalfield an ironstone, locally known as the Three Band or Whitestone Ironstone, lying 30 ft. below the Smithy Coal, was formerly raised at Hockley Hall and Dosthill. This appears to be a local development. Further north at the Kettlebrook Colliery the White Ironstone, in two thin bands of 4 in. and 6 in. respectively, lies 2 ft. above the Smithy Coal, here of workable thickness. Around Glascote and Amington the White Ironstone, in the form of balls and cakes, was extensively worked previously to 1879 and is said to have yielded from 850 to 900 tons per acre.

Leicestershire.

By W. Gibson.

"Ironstone is fairly abundant in the Coal Measures; but, from its not having been much worked, is probably of inferior quality. Iron was formerly smelted from the thin bands and nodules in these measures, the remains of old furnaces being still existent at Moira." ('The Geology of the Leicestershire and South Derbyshire Coalfield,' *Mem. Geol. Survey*, 1907, p. 112.)

Many of the chief workable seams of coal have ironstones associated with them, but no effort is made to raise the ironstone with the coals. Ironstones are usually abundant above the Kilburn or lowest workable coal of the South Derbyshire Coalfield.

South Staffordshire and Worcestershire.

By W. Gibson.

GENERAL ACCOUNT.

Towards the middle of last century the South Staffordshire Coalfield was considered as one of the most important in proportion to its area both as a producer of ironstone and for the manufacture of wrought iron of superior quality. At the present day, except for the raising of local ores for making special classes of iron, South Staffordshire is scarcely reckoned among the producing ironstone fields of Great Britain. Thus the output of ironstone has fallen from over 2,000,000 tons in 1866 to under 40,000 tons in 1916. As a producer of special qualities of iron it still maintains pre-eminence and it is for this purpose the local ores are now utilised. Formerly the native ore used in the manufacture of all classes of iron amounted to more than one-half of the total,[1] whereas at the present day the native ores furnish only one twenty-fifth of the ironstone sent to the furnaces.

A complete account of the geology of the district, the occurrences, distribution, character and analysis of the ironstones is given in the Geological Survey Memoirs on 'The Iron Ores of Great Britain, Part 2. South Staffordshire,' 1858, and on 'The South Staffordshire Coalfield,' 2nd Ed. 1859. Both memoirs remain the standard works on the subject.[2]

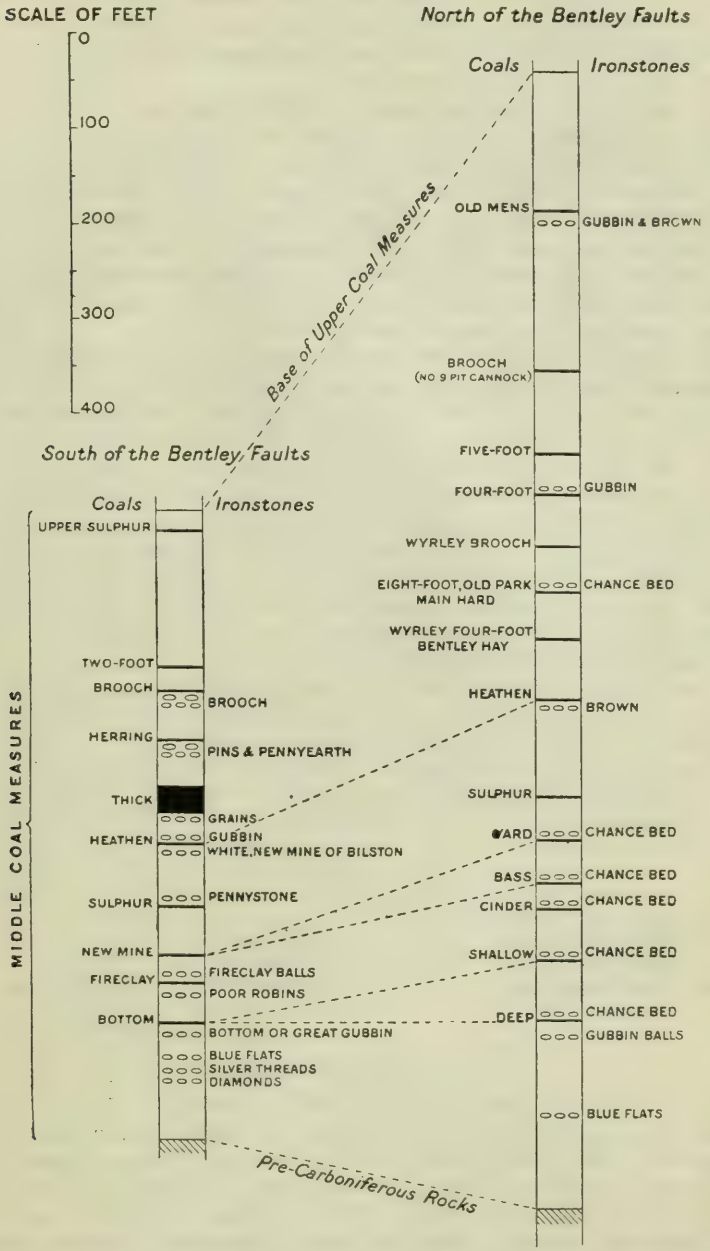
The coalfield can be defined as a broad anticline from which the originally overlying Permian and Triassic rocks have been denuded. The anticline is broken by the three minor anticlines of Dudley, Netherton, and Barr, bringing the Silurian rocks to the surface. Three much faulted synclines lie between the minor anticlines. On the east and on the west the coalfield is bounded by dislocations termed the Eastern Boundary Fault and the Western Boundary Fault. The coals and ironstones have been proved to the west at Baggeridge and to the east at Sandwell Park and Hamstead. Among many faults traversing the coalfield and breaking it up into fault-bounded blocks north of Walsall and Wolverhampton, two faults, known as the Bentley Faults, trend east and west and divide the coalfield into two parts. The ironstones, in the past, were obtained from the area lying south of these faults or in the district lying adjacent to the north. Most of the area to the north, both as regards coals and ironstones, is of comparatively recent development.

Both the Upper and Middle Coal Measures are represented. The ironstones are confined to the Middle Coal Measures, in which they are evenly distributed throughout the lower two thirds (Fig. 8, p. 59). The several courses are close together in the south, but become more widely separated in proportion as the Middle Coal Measures expand from 659 ft. in the south to 1,250 ft. in the north. The ironstones are always in close proximity to seams of coal.

[1] J. Jones, Birmingham and the Midland Hardware District, *Rep. Brit. Assoc.* for 1865, p. 60, published separately, London, 1866.

[2] Both are out of print.

FIG. 8.—*Sections illustrating the Ironstones of South Staffordshire.*



They occur chiefly as nodules or cakes; sometimes in the form of bands from 1 to 12 in., but never exceed 2 ft. in thickness.

Most of the ironstone is obtained from coal-shafts, only a very small quantity being picked out from open clay-workings. The coalfield is not suited for opencast workings as much of it is covered with drift sands and gravels from 20 to 70 ft. in thickness.

Analyses are given facing p. 63. With the exception of the Grains, Cakes or Blue Stone and the Rough Hill Whitestone, which are capricious in their occurrence but unusually rich in manganese, the ironstones do not show much variation from the clay-ironstones of other coalfields.

An output of 2,500,000 tons in 1856 (falling to 1,350,000 tons in the disastrous year of 1857) shows the capacity of the district at its maximum. From 1857 the output gradually declined to 177,000 tons in 1882 and to 39,566 tons in 1916. Roughly about 40,000 tons represent the amount of native ore used in the production of all-mine pig. This amount is obtained from pits raising coal; the quantity of ironstone raised from single pits does not exceed 6,000 tons per annum, the balance being made up by lesser amounts from several coal-mines.

In 1916 the pig-iron produced amounted to 410,302 tons, obtained from 984,421 tons of ore; in 1856 the pig-iron output is returned at 777,171 tons; so that with nearly double the output of pig-iron the district was more than self-supporting.

In the Visible Coalfield, south of the Bentley Faults, most of the ironstone is exhausted. The chief reserves lie about Rowley Regis, Old Hill, Pensnett and Tipton, and in other limited areas, now waterlogged. In the Concealed Coalfield reserves of White Ironstone at Baggeridge and of Gubbin Ironstone at Hamstead exist in considerable quantities and can be obtained in working the Thick Coal. The total reserve of the proved areas amounts to 11,520,000 tons.

North of the Bentley Faults no reliable estimates can be made, since neither the yield per acre nor the value can be ascertained for many of the ironstones that undoubtedly exist.

The reserves of the ironstones now being raised, apart from a reserve of 320,000 tons of ores not now worked, are tabulated as follows:—

	Areas more or less developed.		Additional reserves.
South of the Bentley Faults including Baggeridge and Hamstead—			
Gubbin and Brooch	7,680,000	.....	7,680,000
White Ironstone	3,520,000	.....	—
North of the Bentley Faults	—	.....	55,000,000
	73,880,000		

Details of the Ironstones.

South of the Bentley Faults.

With the exception of the White Ironstone, those below the Heathen Coal in the area south of the Bentley Faults, possess only an historic interest. Many of them are exhausted and none are being raised, but they constituted important ores in the past and are described in the Geological Survey Memoirs previously mentioned (p. 58), from which the following account is chiefly taken.

Diamonds Ironstone.—"It is separated from the Silver Threads Ironstone by from 6 to 15 ft. of bind, etc. The measure is from 2 to 4 ft. thick, containing two layers of ironstone from 2 to 4 in. each. It is occasionally mentioned as recognisable near Wolverhampton, but as a workable bed it is confined, like the Silver Threads to the district just west of Walsall."

Silver Threads Ironstone.—" This seems to be confined to the district round Walsall. It occurs from 5 to 14 ft. below the Blue Flats. The measure consists of clay from 4 to 7 ft. in thickness, containing two or three bands of ironstone, each from 1 to 4 in. in thickness."

Blue Flats Ironstone.—" This ironstone is so called from the flat pavement-like form in which it occurs, together with its weathering of a dull purplish blue after exposure to the atmosphere. It is confined absolutely as a workable measure, to the district between Wolverhampton and Walsall, being scarcely known south of Bilston on the one hand, nor north of Bloxwich on the other. At Park Hall, just south of Wolverhampton, the measure consists of:—topstone 6 in., binds, etc., 2 ft.; second-stone 3 in., parting 1 ft. 3 in., third-stone 4 in.; ground with chaterstone 4 ft. 2 in., bottom stone 3 in.; on the Bentley Estate: ironstone 4 in.; binds 3 ft., ironstone 1 in., binds 1 ft. 6 in.; ironstone 2 in.; at Ryecroft: ironstone cake 3 in.; blue clod 1 ft.; ironstone 3 in."

At the present day the surface of the ground between Walsall and Willenhall is thickly cumbered with the old spoil-banks thrown up in working the ironstone. Some of the ironstone is said to remain, but how much is uncertain, as the plans of former workings are imperfect and do not faithfully record the amount of ironstone worked out. The Blue Flats Ironstone is mentioned in some of the modern pits going below the Deep Coal in the northern part of the Cannock Chase area, but no reference is made to its yield or character.

Gubbin and Balls Ironstone (*also known as Bottom or Great Gubbin*).—" This as a measure containing good workable ironstone, occurs only between Wolverhampton and Walsall, and around Bilston. At Chillington Colliery it had the following form:—balls of ironstone 8 in.; clod 2 ft. 6 in.; balls of ironstone 6 in.; dark clod 1 ft. 6 in; gubbin ironstone 6 in.; clod 1 ft.; gubbin ironstone 3 in."

Rough Hills Whitestone.—" This ironstone appears to be confined to the district between Bilston and Wolverhampton. At Parkfields the measures were 19 ft. 2 in. thick, containing 11 bands of ironstone from 1 in. to 6 in. thick, making a total of 32 in. of ironstone; but elsewhere it is never more than 3 or 4 ft. thick, with not more than 6 or 8 in. of ironstone."

The Poor Robin, Getting Rock and Fireclay Balls ironstones are described by Jukes as variable and capricious in their occurrence, that of the Poor Robin being the most widely diffused. The Pennystone (Bluestone and Cakes) Ironstone is also of irregular occurrence.

White Ironstone.—The previously mentioned ironstones are of local occurrence. The White Ironstone, on the contrary, has been worked from near Walsall as far south as the Hawne Colliery near Halesowen. A large proportion of the stone has been gotten over the Exposed Coalfield but considerable reserves lie in the Concealed Coalfield west of the western Boundary Fault. In the Exposed Coalfield the measures are stated to consist of from 3 to

7 ft. of clunch and bind containing from 2 to 4 bands or courses of ironstone, each of which varies from an inch to a foot in thickness. At Baggeridge the ironstone occurs in two bands, from 4 to 9 in. thick, in 6 ft. of measures which contain a chance stone from 2 to 6 in. thick. The average yield is 12 cwt. per cubic yard. Some Whitestone remains in the Pensnett area. In the districts of Oldhill and Blackheath the stone is said to be poor and lean.

Analyses give 27 to 36 per cent. metallic iron. Silica ranges from 9 to 16 per cent., and alumina from 2 to 10 per cent. Phosphorus and sulphur are low.

Gubbin Ironstone.—This is the most constant measure of ironstone in the district. The measures consist principally of dark clunch from 2 to 9 ft. thick with the ironstone occurring in one, two, or three layers of nodules. In the neighbourhood of Tipton an ironstone, called the Lambstone, occurs in the measures immediately above the Heathen Coal and is separated from the Gubbin Ironstone by about 6 ft. of measures. This ironstone is distinct from the Lambstone (p. 63) found below the Heathen Coal north of the Bentley Fault. A detailed section of the Gubbin measures at Upper Gornal gives: ironstone (called Gubbin) 6 in.; dark clunch 2 ft.; ironstone (called Cannock) 6 in.; dark clunch 2 ft.; ironstone (called Rubble) 3 in.; black batt 6 in.

The Gubbin Ironstone was one of the chief stones and was got by holing-up through the Heathen Coal and excavating bell-shaped chambers in the ironstone measures. The lower part of the Heathen Coal was left in the ground, the ironstone having been more valuable than the coal. When the Heathen Coal is intact, the Gubbin Ironstone is got with it, and such ironstone as remains where the lower part of the coal is now being got. The yield varies from 8 to 15 cwt. per cubic yard. In the Exposed Coalfield the bulk of the Gubbin Ironstone has been exhausted. On the west side of the coalfield the Gubbin does not prove a good stone, being siliceous and high in sulphur and phosphorus. On the east side at Hamstead the Gubbin is of good quality but it could be obtained only as the Thick Coal is worked out. The Gubbin is generally considered to yield about 40 per cent. metallic iron, but analyses show a range between 32 and 39 per cent. Phosphorus is low, but varies more than in the Whitestone. Sulphur also is low.

Grains Ironstone.—This is an exceedingly good stone, but only occasionally present and is too thin to be of value.

Brooch Ironstone.—Several courses of ironstone occur above the Thick Coal. None compare favourably with the ironstones below, and practically only the Brooch stone is now raised for sale. A chance stone overlies the Thick Coal and is picked out in working this coal, more particularly at Hamstead where about 100 tons per week is thus obtained. The Pins and Pennyearth ironstones contain much dirt and are only accepted during a shortage of better stones.

Analyses of Ironstones, South Staffordshire.

('Iron Ores of Great Britain,' pt. ii, *Mem. Geol. Surv.*, 1858, pp. 115—164.)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)
Ferrous oxide	43·81	45·35	37·69	54·12	46·30	45·86	40·28	30·96	48·63	33·92	50·60	43·55	46·39	47·87	49·61	44·20	33·19	46·56	39·51	52·04	49·04	49·30	42·34	40·39	40·01	41·90	46·14
Ferric oxide	—	—	—	—	—	—	—	—	—	2·77	—	—	—	—	—	—	—	2·80	—	—	3·39	3·61	1·47	2·38	2·46	—	—
Manganous oxide	0·98	0·56	0·61	2·05	1·44	0·96	0·54	0·73	1·29	0·77	3·30	1·65	1·01	1·12	0·98	2·43	2·02	0·65	0·94	0·92	0·79	0·86	1·12	0·75	0·75	0·72	1·40
Alumina	1·05	0·61	8·24	0·78	0·44	0·42	0·52	0·13	0·57	0·67	0·24	0·23	0·54	0·43	0·50	0·37	7·71	0·70	1·12	1·30	0·21	0·34	0·59	0·19	0·46	5·26	3·53
Lime	1·52	2·60	2·72	2·21	0·76	1·17	0·84	1·84	4·45	2·45	1·19	1·53	1·03	1·00	1·86	0·96	1·24	1·13	2·11	0·53	0·70	0·69	3·89	7·30	2·58	3·47	3·43
Magnesia	1·15	1·22	2·60	0·62	0·94	1·65	1·33	2·90	0·80	4·11	1·98	4·65	1·33	1·27	1·86	1·04	1·04	1·18	2·76	0·85	0·57	0·45	1·48	2·16	2·70	4·89	2·13
Carbon dioxide	28·22	30·21	25·92	35·25	30·44	31·02	26·53	22·13	32·16	26·89	35·47	34·00	30·00	30·96	33·05	29·03	20·94	30·08	28·08	32·31	30·80	32·05	30·91	33·35	29·13	31·94	32·04
Phosphoric acid	0·83	0·46	0·66	0·69	0·74	0·21	0·30	0·26	0·31	0·35	0·23	0·15	0·11	0·07	0·34	0·66	0·50	0·38	0·31	0·21	0·18	0·23	0·25	0·22	0·21	0·22	0·61
Sulphuric acid	trace.	trace.	trace.	trace.	trace.	trace.	trace.	trace.	0·06	—	trace.	0·06	0·10	0·08	0·10	0·05	0·04	—	trace.	trace.	—	—	trace.	—	—	0·06	trace.
Silica, insoluble	0·46	0·67	18·11 (total)	2·11	0·12	0·42	0·87	0·15	0·33	0·09	0·27	0·34	—	—	—	0·98	22·48 (total)	0·54	—	—	0·27	0·23	0·35	0·18	0·27	9·95 (total)	8·63 (total)
Iron pyrites	0·30	0·20	0·22	0·40	0·07	0·10	0·09	0·12	0·16	0·15	0·13	0·47	0·17	0·17	0·17	0·26	0·41	0·13	0·05	0·13	0·11	0·13	0·06	0·11	0·06	0·56	0·10
Potash	—	—	0·43	trace.	—	—	—	—	—	0·14	—	—	—	—	—	—	0·90	0·23	—	—	0·10	0·09	—	0·07	0·19	0·87	0·41
Sulphide of zinc	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1·27	—	—	—	—	—
Water at 100° C.	0·54	} 1·64	1·29	1·07	1·38	1·08	1·69	{ 0·56	0·32	0·42	} 0·47	0·64	1·50	1·18	1·30	undet.	undet.	1·07	0·98	0·46	{ 0·26	0·37	0·28	0·33	0·39	} 0·82	0·94
Water, combined	1·32							{ 1·83	1·23	0·98											{ 0·77	0·29	0·73	0·60	0·72		
Organic matter	0·88	1·59	1·56	1·36	1·14	0·90	1·99	0·10	0·28	0·47	undet.	undet.	0·21	0·41	1·24	2·68	9·87 (about)	0·50	0·52	0·51	0·60	0·54	0·56	0·80	1·06	0·42	0·98
Ignited insoluble residue	18·80	15·87	—	—	15·26	15·90	24·06	37·90	9·40	25·55	5·52	11·95	18·39	15·95	10·02	17·04	—	13·77	22·96	11·14	12·15	9·42	15·50	10·52	18·77	—	—
	99·86	100·98	100·05	100·66	99·03	99·69	99·04	99·61	99·99	99·73	99·40	99·22	100·78	100·51	101·03	99·70	100·34	99·72	99·34	100·40	99·94	99·87	99·53	99·35	99·76	101·08	100·34
Ignited insoluble residue—																											
Silica	12·40	9·96	Given as clay 25·51	Given as clay 8·43	10·17	10·26	18·20	26·35	5·88	18·14	3·31	7·47	11·71	10·52	6·26	Not given.	Not given.	7·72	16·31	6·63	7·67	5·99	10·82	6·56	13·45	Given as clay 14·67.	Given as clay 13·38.
Alumina	5·11	5·09			4·36	5·44	4·46	9·45	3·07	5·77	1·63	3·47	6·04	5·02	2·35			4·70	5·13	3·68	3·55	2·71	3·65	3·08	4·22		
Ferric oxide	0·39	0·54			0·13	0·46	0·52	1·15	0·04	0·40	0·38	0·84	0·57	0·33	0·53			0·39	0·85	0·43	0·36	0·21	0·11	0·37	0·59		
Lime	0·15	trace.			traces.	0·20	0·68	trace.	trace.	0·20	0·03	0·19	0·09	0·13	0·03			0·11	trace.	trace.	0·09	0·17	} traces	{ 0·04	0·08		
Magnesia	trace.	0·04			traces.	0·20	0·14	0·21	trace.	0·32	0·06	0·09	—	—	—			0·15	0·30	0·33	0·09	0·07		{ 0·06	0·14		
Potash	0·42	0·36			undet.	undet.	undet.	0·74	0·11	0·60	undet.	undet.	0·28	0·38	0·39			0·82	0·65	0·32	0·32	0·21	0·84	0·26	0·18		
Manganous oxide	—	—			—	—	—	—	—	—	—	—	—	—	—			trace.	—	—	trace.	—	trace.	trace.	trace.		
Metallic iron	34·35	35·74	29·42	42·26	36·14	35·99	31·70	24·88	37·45	28·87	39·71	34·88	36·56	37·47	39·02	34·53	26·01	38·56	31·34	40·84	40·81	41·06	34·41	33·44	33·28	32·87	35·95

(1) Brooch Ironstone, Corngreaves. (2) Pins, Dudley. (3) Penny Earth, Dudley. (4) Grains, Dudley. (5) Gubbin Ironstone, Gubbin, Dudley. (6) Gubbin Ironstone, Cannock, Dudley. (7) Gubbin Ironstone, Rubble, Dudley. (8) Whitestone Bind, Dudley. (9) Bottom Whitestone, Dudley. (10) White Stone, Rough Hay Colliery, Darlaston. (11) Cakes, or Blue Stone, Dudley. (12) Cakes, or Blue Stone, Dudley. (13) Fireclay Balls, Dudley. (14) Fireclay Balls, Dudley. (15) Poor Robin's, Bunkers Hill. (16) Rough Hill Whitestone (good sample) Darlaston. (17) Rough Hill Whitestone (bad sample), Darlaston. (18) Rough Hill Whitestone, Rough Hay Colliery, Darlaston. (19) Gubbin and Balls, Bunkers Hill Colliery. (20) Gubbin and Balls, Bunkers Hill Colliery. (21) Gubbin and Balls Balls, Rough Hay Colliery, Darlaston. (22) Gubbin and Balls, Gubbin, Rough Hay Colliery, Darlaston. (23) Blue Flats Ironstone, Rough Hay Colliery, Darlaston. (24) Silver Threads, Rough Hay Colliery, Darlaston. (25) Diamonds, Rough Hay Colliery, Darlaston. (26) Diamonds, Darlaston. (27) Brown Stone, Bloxwich.

Though the Brooch Ironstone is also a stone inferior to those below the Thick Coal it is raised in conjunction with the Brooch and should be regarded as an ironstone associated with a good seam of coal and which it would not pay to get as an ironstone. In the district of Old Hill it is said to occur as a layer from 3 to 5 in. thick. Some analyses give from 30 to 35 per cent. metallic iron.

North of the Bentley Faults.

(From notes by H. Dewey.)

North of Bloxwich several ironstones are got in limited quantities, totalling under 2,000 tons per annum. These ironstones do not receive names nor can they be correlated satisfactorily with the ironstones south of the Bentley Faults. In nearly all cases the ironstone raised is that which falls in the mine-roads during the ripping of the coals.

In such pits as have been sunk below the Bottom or Deep Coal, ironstones, in the position of the Diamonds, Silver Threads and Blue flats are found. No account of their yield and composition can be obtained.

The Deep Coal roof contains nodules and bands of ironstone from 1 to 2 in. thick. They can be regarded as chance stones and are sent to the surface together with similar chance ironstones occurring in the roof of the Shallow Coal. Where the Bass Coal is being worked two or three bands of ironstone up to 3 in. thick are picked out from the roof shales. South of Bloxwich two ironstones of good quality are stated (Iron Ores of Great Britain, p. 109) to occur in the following position:— Heathen Coal, clunch and ironstone 9 ft. 10 in.; lambstone ironstone 3 in.; clunch 2 ft. 6 in.; black batt 1 ft.; brownstone ironstone 6 in.

Some parts of the stone were found to contain not less than 30·17 of organic matter (*op. cit.*, p. 163) and would thus belong to the class of blackband ironstones, an ironstone of exceptional occurrence in South Staffordshire. The Bloxwich area, however, contains numerous igneous intrusions and it is doubtful if this ironstone would repay a search for it. An analysis of the non-carbonaceous ironstone gives 35·95 per cent. metallic iron. At Aldridge, nodules of ironstones lying in shale and batts, are worked with the Four Foot Coal which is 380 ft. above the Yard Coal and are estimated to yield about 266 tons per acre. An ironstone above the Four Foot Coal of Walsall Wood Colliery resembles a blackband, but, though rich in iron, the calcined stone gives much cinder and ash.

CHAPTER VI.

CARBONIFEROUS BEDDED ORES (*contd.*).

North Staffordshire.

By H. Dewey.

General Account.

North Staffordshire contains the Potteries Coalfield with an area of 100 square miles, the Cheadle Coalfield with an area of 18 square miles, and a small area of about 2 square miles, is the Shaffalong Coalfield. In the first two coalfields ironstones are being raised. They are described in the Geological Survey Memoirs on 'The Geology of the North Staffordshire Coalfields,' 1905, and 'The Geology of the Cheadle Coalfield,' 1903, from which the greater part of the following account has been taken.

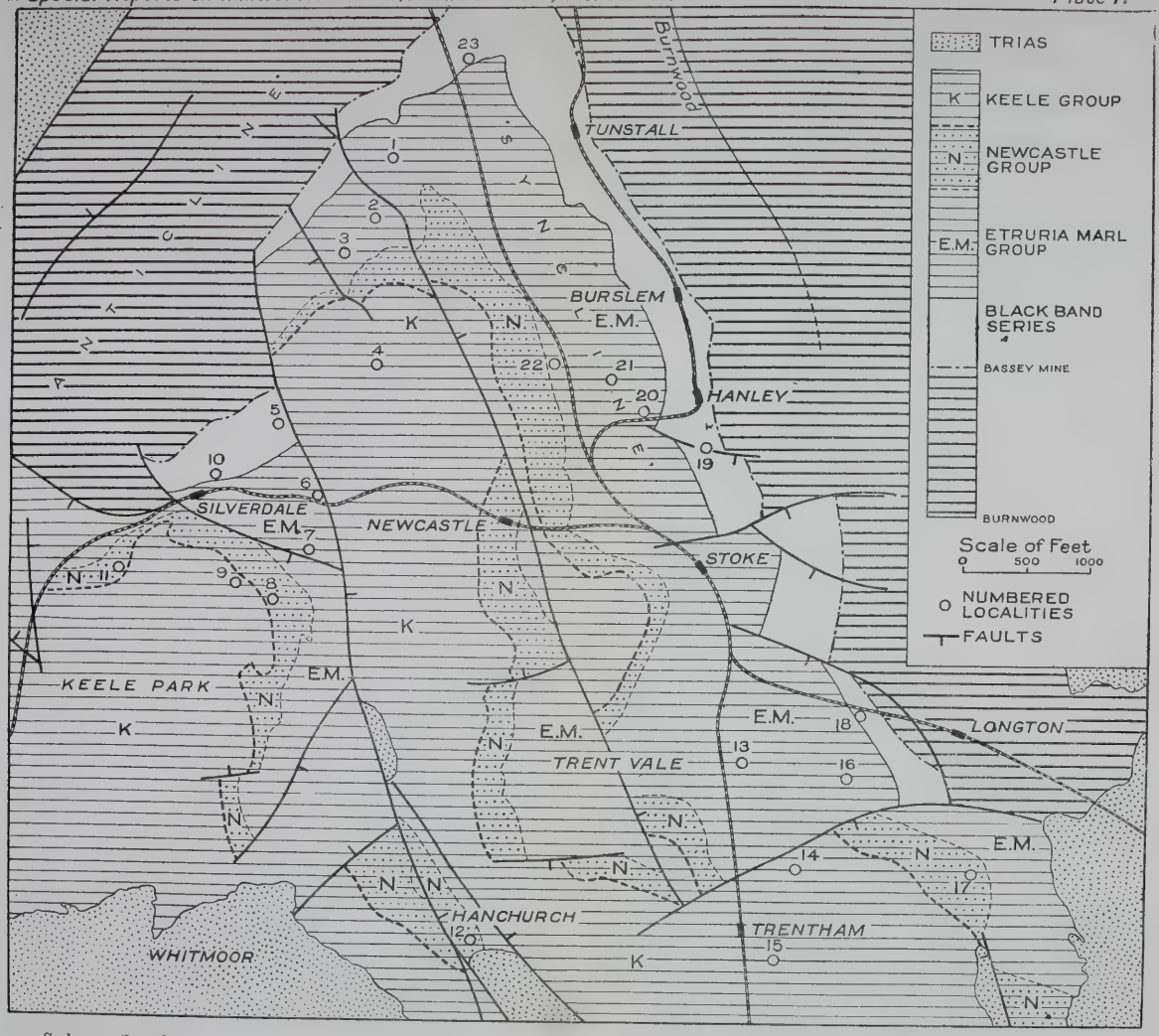
In the area chiefly occupied by the Pottery towns the Coal Measures are arranged in a deep fold in the form of a triangle, of which the apex lies a little north of Biddulph, with the base, about 10 miles in length stretching from Apedale to Longton (sketch map Plate 1). West of this trough the Coal Measures rise up in a sharp anticline. The Coal Measures, including the beds formerly termed Permian, attain a thickness of 7,000 ft. These measures are separated by a bed of coal called the Bassey Mine into a lower group 5,000 ft. thick, and an upper group over 2,000 ft. in thickness.

'Blackband' ironstones are characterised by the fact that they contain enough carbonaceous matter to produce a dark-brown to black colour, and to support combustion, their calcination being possible without the use of coal. They are argillaceous carbonates, and always occur in the form of beds. In specific gravity they range from 2 to 2·3.

The 'Lean Mines' are also argillaceous carbonates but do not contain carbonaceous matter except occasionally, when they are termed semi-blackbands. They occur as nodules enclosed in clay or shale, or form beds. Sometimes the nodules unite into an irregular band, and frequently show fissures lined with white hydrated silicate of alumina or carbonate of lime, or contain crystals of zinc blende, galena and iron-pyrites. In specific gravity they range from 3 to 3·5.

All these ironstones lie in a small thickness of measures, the blackbands occurring in 450 ft. of measures above the Bassey Mine Coal and the Lean Mines in about 1,000 ft. of measures below that coal. (Plate III., p. 68). No other useful ironstones (except locally the Top Two Row) are known in the remaining beds above or below these two groups.

The higher unproductive subdvisions of the Coal Measures cover considerable areas of the Pottery Coalfield (Plate I., p. 64), but beneath them the productive ironstone-measures lie at workable depths.



Scale one mile to the inch.

Geological Sketch Map of the Pottery Coalfield showing the outcrop of the Blackband Ironstone Measures.

List of Localities.

1. High Carr.
2. Parkhouse.
3. New Hem Heath.
4. Holditch.
5. Whitebarn.
6. Knutton Farm.
7. Millbank.
8. Keele Home Farm.
9. Keele Bogs Cottage from Silverdale Collieries.
10. By Silverdale Station.
11. Hollywood.
12. Hanchurch.
13. Great Fenton.
14. Blurton Oaks from Fenton Colliery.
15. Newstead.
16. Longton Hall.
17. Florence.
18. Oldford No. 4. Pit.
19. Rowhurst Pit.
20. Racecourse Pit.
21. Grange.
22. Wolstanton.
23. Holly Wall.

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The Cheadle Coalfield is bounded on the north by an outcrop of Millstone Grit and on the south the measures pass under Bunter Pebble Beds. The Blackband measures of the Pottery Coalfield are absent and the only ore worked is a bed of brown hæmatite which is locally developed at the base of the Coal Measures immediately above the Millstone Grit. It is practically exhausted.

The Shaffalong Coalfield contains only the lowest part of the Coal Measures in which workable ironstones are absent.

Although iron-ore has long been mined in North Staffordshire the date of its discovery is unknown. The earliest mention of it is by Plot in 1686 when it was being sent away from the district to the furnaces of Shropshire and Cheshire. Statistics, for the purpose of imposing a tax on coal raised, show that in 1769 there were two furnaces then in blast in North Staffordshire, one in Apedale producing 728 tons per annum, and the other at Silverdale which made 1,230 tons of pig iron. In 1839 there were 7 furnaces which produced 18,200 tons a year chiefly, if not entirely, from the clay-band ironstones.[1] By 1884 the number had increased to 39, while the quantity of pig-iron produced had risen to 296,000 tons, and of ironstone raised to 1,783,800 tons per annum. Since that date the output of ore has fallen gradually from about 1,000,000 tons in 1898, 900,000 in 1908 to 700,000 in 1916. In the same period the quantity of pig-iron made has fluctuated between 200,000 and 313,000 tons per annum. The quantity of Mesozoic ores used is on the increase.

The iron made is chiefly forge-pig; the output of all kinds in 1916 being Forge 153,000 tons, Foundry 73,000 tons, and Basic 87,000 tons.

The blackband ironstones in the raw state contain from 29 to 39 per cent. of metallic iron: ·43 to 1·0 of phosphoric acid; a trace to 1·7 of sulphuric acid and ·64 to 11·2 of lime. The clay-bands in the raw state contain from 25 to 46 per cent. of metallic iron; ·4 to 2·76 phosphoric acid; a trace to ·21 sulphuric acid, and 1·24 to 5·07 lime. Complete analyses are given on pp. 84–86.

In the following estimates of the reserves the Blackbands and the Lean Mines (including the semi-blackbands, the Chalky and the Burnwood) have been calculated separately. The factors taken into consideration are the acreage of the outcrop; the parts of this area that are exhausted or unworkable; the average thickness of each seam and its yield in tons per foot-acre. The last factor varies, but for the Blackband ironstones the figure accepted by the principal owners is 1,890 tons per foot-acre of calcined stone. It is a conservative estimate, and allows for faulty ground, local diminution in thickness and deterioration in quality. One firm uses for working purposes as low a figure as 1,600 tons per foot-acre (calcined), and their experience is that the balance is always on the right side. At Longton it is known that locally the Bassey Mine yields up to 5,000 tons per foot-acre of raw stone, but this is perhaps exceptional.

[1] H. Scrivenor, 'History of the Iron Trade,' 1854, p. 57.

The condition of the ground as regards flooding varies from mine to mine, and though it does not affect the amount of reserves, it has been thought advisable to omit from the estimates some areas which are unlikely ever to be drained. The extent of workings and the degree of exhaustion of the ironstones are difficult to ascertain; certain areas are known to be worked out, in others only pillars remain, while in some localities the ores lie among fallen material from roof or walls.

The estimated yield for unworked ground is based upon the average of contiguous worked areas and upon such data as have been obtained, namely those from one sinking and three borings.

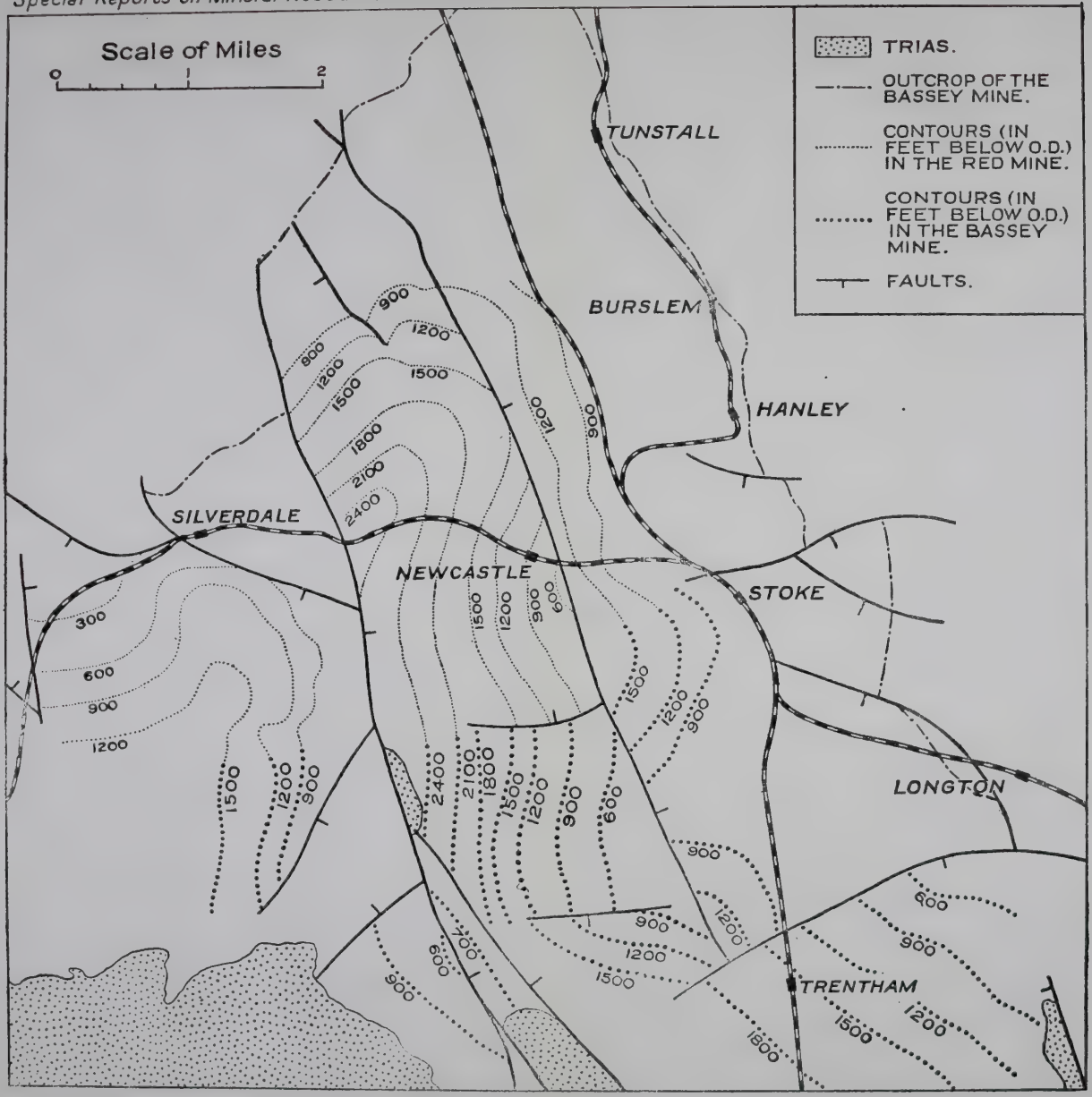
The lowest valuable lean-mine is the Burnwood. The outcrop of this seam is well known on the eastern side of the syncline but is less well defined on the western side of the coalfield. With the exception of the Chalky and the Burnwood none of the lean mines persist throughout the coalfield, but the dying out of one seam is apt to be accompanied by the appearance of others at slightly different horizons. Their total average thickness cannot be much less than 9 ft. and their average yield per foot-acre 1,600 tons. Some of the seams have been worked extensively, especially the two semi-blackband seams, the Chalky and the Burnwood. Near Sneyd Green and Burslem the latter seam is nearly worked out, but it is a good stone. On nearing Fenton it changes into a ' Lean Mine ' but is still of fair quality.

As the Blackband ironstones were scarcely worked until about the middle of the 19th century the returns of output from North Staffordshire refer mainly to the lean mines. The total tonnage of ore extracted between the years 1882 and 1916 amounted to about 36,000,000 tons. Most of this came from the eastern side of the coalfield and from the neighbourhood of Silverdale, hence there remain large reserves in the area between the Apedale and the Newcastle faults, and in the south of the field generally.

According to Warington Smyth the reserves of 7 or 8 of the ' Lean Mines ' amount to about 984 million tons of raw stone; more recent statistics however indicate the figure for calcined stone at 658 million tons or 940 million tons of raw stone.

Of the four blackbands the upper three are usually worked and calcined together, namely the Halfyards, the Red Shagg and the Red Mine. The approximate thicknesses in feet of the Red Mines and the Bassey Mine are given in the following table, the localities in the west being given on the left, those on the north in the centre, and those in the south on the right.

Name of Seam.	Silver-dale.	Knutton Manor.	Chester-ton.	Goldenhill and Golden-dale.	Cobridge and Hanley.	Long ton.
Blackbands or Half-yards ...	1¼–1½	1–2	1–1½	½	1–1¼	Absent.
Red Shagg ...	2	2½–3	2–3¾	–	2½	Absent.
Red Mine ...	2	2 to 5½	2 to 5¾	–	2	Absent.
Bassey Mine ...	⅓	–	⅓–⅞	5	2	1–6



Map showing approximate contours in Feet below O.D. in the Red Mine and the Bassey Mine; key map furnished by Plate I.

To face page 67.

The Bassey Mine Ironstone was well developed in the eastern part of the coalfield and was worked opencast from Shelton northward by the east of Burslem and Tunstall round the syncline to Broadfield and the faulted area beyond. It covers a much greater area than that of the Red Mines, for it persists many miles further south, and although its limit in that direction is unknown it has been proved in several boreholes to maintain its quality. On the east near Newstead Farm, about half-a-mile south-east of Trentham Station, it was found at a depth of 1,946 ft. and was there a foot thick. Near Hanchurch, nearly 3 miles to the west, it has also been proved, but not west of this. An east and west line may provisionally be accepted about a mile south of these places as the southern limit of the area of reserves. Allowance must be made for the probability of the ironstone having become converted into limestone further west, in a similar way to the Red Mines, and for other factors.

The total area under which reserves may be expected is approximately $28\frac{1}{4}$ square miles, giving with a yield per foot-acre of 1,890 tons, a reserve of 68,000,000 tons, calcined ore.

The Red Mines are practically worked out from their outcrop near Burslem to the Bradwell Wood Fault, and farther south, near Cobridge, Shelton and Hanley, are largely exhausted. On the west also, in the Silverdale district north of the Millbank Fault, they are practically worked out. There are, however, large reserves near Chesterton, Knutton, and in the area lying between the Apedale and the Newcastle Faults where they have recently been proved beneath the barren measures north of Newcastle-under-Lyme.

Their southerly extent is well known on the eastern side of the coalfield, for they have never been found south of Stoke, in the numerous shafts sunk to the Bassey Mine Ironstone. On the west the beds extend south of the latitude of Stoke, for they were proved to be $1\frac{1}{2}$, 3 and $2\frac{2}{3}$ ft. thick respectively, at the boring near Home Farm, Keele, at depths ranging from 1,395 to 1,509 ft., and also in underground workings nearer to Silverdale.

Their westerly limit is determined by their lateral change into limestone. Between Keele and Madeley they have long been known to occur in this form and it is believed that they are in this condition west of Halmer's End. A line may therefore be drawn between the two districts west of which the reserves are likely to be negligible.

The total area where the Red Mines are likely to occur may be taken as 18 square miles, giving a reserve of approximately 114,000,000 tons, calcined ore.

The practicability of gaining the ironstone in the unworked areas depends partly upon the thickness of the overlying rocks. In the case of the Blackband ironstones an attempt has been made to show on a map (Plate II, p. 67) the depth in feet below the Ordnance datum of the Bassey Mine and the Red Mine. To calculate from this map the depth to the Bassey Mine where the Red Mine only is shown, another 300 ft. should be added in the south, and 250 ft. in the north of the area indicated.

On the western side of the Western Anticline the beds in the upper workings dip steeply westwards, but they flatten out rapidly near the 'Western Boundary Fault.' The total displacement of this belt of disturbance probably does not fall far short of 800 yards. To the west of it an area of Coal Measures about three square miles in extent undoubtedly exists, under which the Pottery Bassey Mine would be between 650 and 1,000 ft. below the surface, but whether this and the other blackbands are workable is unknown. They are likely to be of inferior quality and to take the form of ferruginous limestones.

Details of the Ironstones.

The Potteries Coalfield.

'Lean Mines' and 'blackbands' are worked in this coalfield. The meaning of the terms is defined on p. 64.

The Lean Mines.—All the Lean Mine ironstones lie in the measures beneath the Bassey Mine. Their relative position to the Blackband ironstones and to one another is shown in the vertical sections (Plate III, p. 68) which also illustrate the variation in thickness of the Coal Measures at different parts of the coalfield. As many of the beds are impersistent over the district no complete correlation has been worked out.

The outcrop of the Burnwood Ironstone, the lowest useful bed, follows the outcrop of the Bassey Mine and indicates the area within which the Lean Mines occur (Plate I).

The lean mines have been worked from an early period and were used almost exclusively in the North Staffordshire furnaces until the middle of the nineteenth century. They yield an iron of good quality, but at present are being raised at only a few pits. The Gubbin above the Great Row Coal is being worked at Tunstall and Crackley; the Cannel Row at Goldenhill and Clanway; the Pennystone at Etruria, and the Burnwood at Burslem and Newchapel.

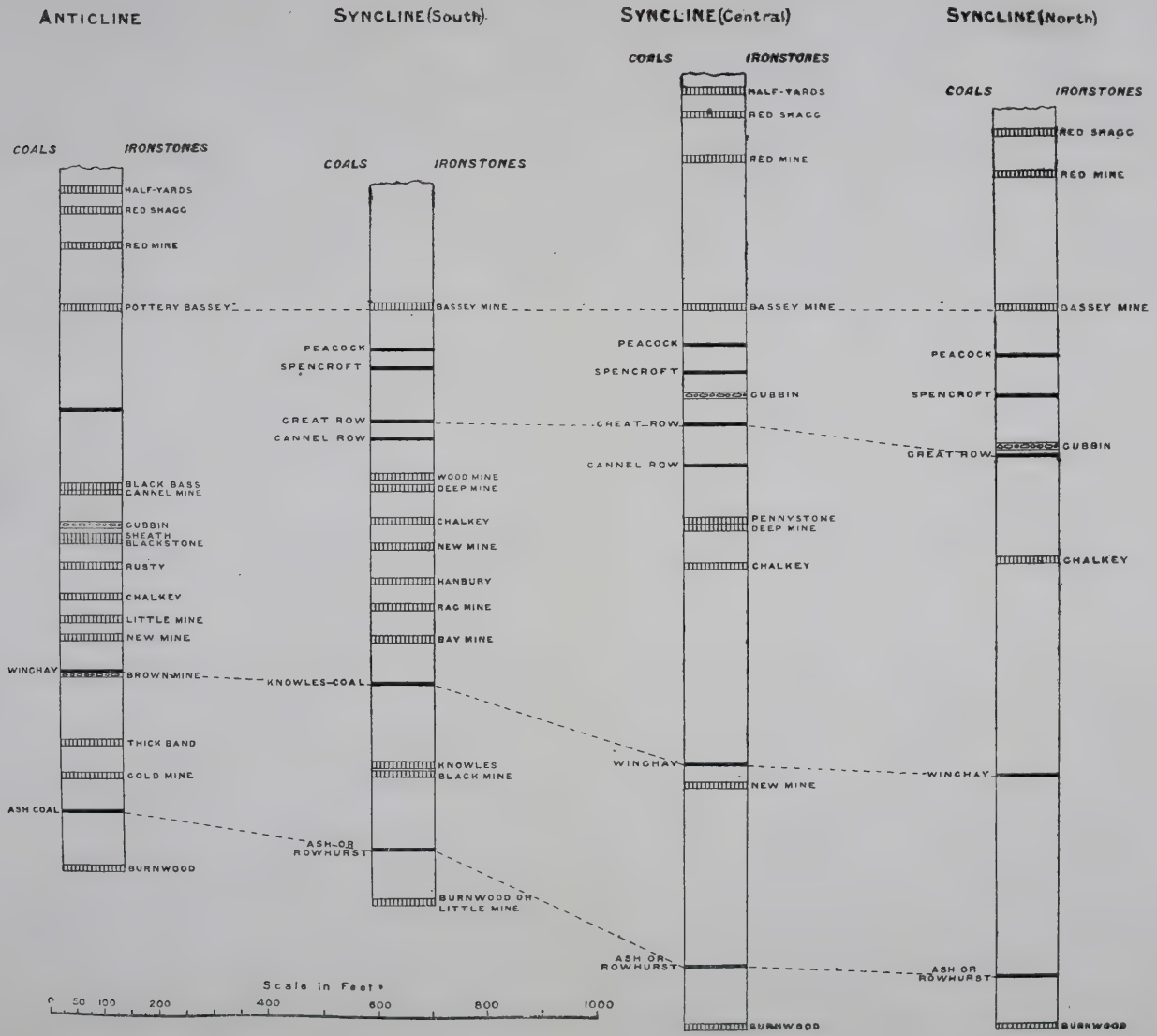
The Cannel Row and Gubbin ironstones are in demand in South Staffordshire on account of their manganese, which averages about 2 per cent.

In the western area of the coalfield the sequence of the Clayband or Lean-mine ironstones, according to Sir John Cadman,[1] is shown in the following table:—

	Ft.
Base of Blackband Series	—
Strata (with Great Row Coal)	324
Black-bass Ironstone	—
Cannel-mine Ironstone	—
Strata	63
Gubbin-mine Ironstone	—
Strata	21
Sheath-mine Ironstone	—
Black-stone Ironstone	—
Strata	42
Rusty-mine Ironstone	—
Strata	57
Chalky-mine Ironstone	—

[1] *Trans. Fed. Inst. Min. Eng.*, vol. xxvi, 1905, p. 108.

General Sections illustrating the Ironstone Measures of the Pottery Coalfield.



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	Ft.
Strata	39
Little-mine Ironstone	—
Strata	31
New-mine Ironstone	—
Strata	69
Brown-mine Ironstone	—
Strata	120
Thick-band Ironstone	—
Strata	63
Gold-mine Ironstone	—
Strata	60
Ash Coal	—
Strata	114
Burnwood Ironstone	—
Strata	825
Top Two-row Ironstone	—

The following list is of the names of the clayband ironstones worked in the eastern area of the coalfield with the names of some of the coals:—[1]

Peacock Coal.	Hanbury Measures Ironstone.
Spencroft Coal.	Ragmine Ironstone.
Gubbin Mine Ironstone.	Knowles Coal.
Great Row Coal.	Priorsfield Ironstone.
Cannel Row Ironstone.	Knowles Ironstone.
Wood Mine Ironstone.	Black Mine Ironstone.
Pennystone Ironstone.	Brown Mine Ironstone.
Deep Mine Ironstone.	New Mine Ironstone.
Chalky Mine Ironstone.	Ash Coal.
New Chalky Ironstone.	Burnwood or Little Mine Ironstone.

Of the many ironstones mentioned in the two lists few have been correlated, and the same name has apparently been applied to more than one seam. The following descriptions are compiled in part from those given by Messrs. Homer, Ward, Cadman, and in the Memoirs of the Geological Survey. *See* Bibliography on p. 83.

Top Two Row Ironstone.—This ironstone occurs only in the western part of the coalfield and was worked at Nabbs Pit, Silverdale, where it contained 20·77 per cent. of metallic iron. It is the lowest useful ironstone worked and lies at a depth of 825 ft. below the Burnwood Coal. It includes three beds of ironstone $3\frac{1}{2}$ ft., $\frac{1}{4}$ ft. and $\frac{1}{3}$ ft. thick, respectively, separated by seams of bass. The whole is underlain by the Top Two Row Coal $2\frac{1}{2}$ ft. thick.

Burnwood or Little Mine Ironstone.—This ironstone lies about 90 ft. below the Ash or Rowhurst Coal. At Longton, Shelton and Burslem it rests directly on the Burnwood or Little Mine Coal, but elsewhere is separated from that coal by seams of bass.

In the southern portion of the coalfield the bed is known as the Little Mine Ironstone; while at Golden Hill, Pitts Hill and Newchapel it is described as the Burnwood Ironstone. At each of these localities it abounds with a molluscan fauna, including *Anthracomya adamsi.*

[1] 'The Geology of the North Staffordshire Coalfields,' *Mem. Geol. Survey*, 1905, p. 214.

From north to south the character of the ironstone changes for whereas at Burslem and Newchapel it is a semi-blackband, at Fenton, near Stoke-upon-Trent, it is an ordinary clay-band ironstone. The stone also decreases in thickness from north to south, but the underlying coal greatly improves in quality in the same direction, which made it possible to work the ironstone at a profit.

Recent analyses show that the Burnwood contains 37 per cent. of metallic iron; ·45 per cent. phosphorus; ·29 per cent. sulphur, and 1·22 per cent. manganese.

At present it is being got to the extent of 20,000 to 30,000 tons a year at Burslem and Newchapel where it is a semi-blackband. It is a good stone but the coal beneath it is poor at Newchapel. At Burslem the seam is 8 in. thick and contains 46 per cent. of metallic iron. It overlies a good coal 2 ft. in thickness. There is, however, a fault which throws the stone down 120 yards west, and all the stone is worked out east of this fault. West of the fault the ironstone has not been worked.

The seam dwindles from 28 in. on the eastern side of the field to 6 in. on the western side.[1] In the Chell district a section showed an upper seam of ironstone $2\frac{1}{3}$ ft. and a lower, $1\frac{1}{2}$ ft. thick separated by $1\frac{1}{2}$ ft. of shale, the lower seam resting on 8 in. of coal. In another pit the ironstone was $1\frac{1}{2}$ ft. with a 5-in. seam of coal under it, itself separated by $3\frac{3}{4}$ ft. of bass from $3\frac{1}{2}$ ft. of coal.

At Great Fenton the ironstone is 2 ft. thick and the underlying coal $2\frac{1}{2}$ ft., whereas at Shelton it is only 1 ft. and the coal 2 ft. thick; and at Burslem 8 in. and the coal 2 ft. There are two bands of ironstone at Newchapel, 2 ft. and 1 ft. 2 in. thick respectively, separated by a seam of bass $1\frac{1}{4}$ ft. thick; while at Fegg Hayes there is only one bed of ironstone $1\frac{1}{4}$ ft. thick separated from the Burnwood Coal by $1\frac{1}{2}$ ft. of bass.

The Billy Mine Ironstone.—This stone is found in the neighbourhood of Shelton lying at about 200 ft. above the Rider Coal and is from 6 to 9 in. thick. Warington Smyth remarks on its conglomeratic character. (Iron Ores of Great Britain, Part IV, p. 275.)

Gold Mine Ironstone.—This stone has been recognized only in the western area, where it varies considerably in thickness and quality, and appears to occupy a position between the Ash Coal and the Knowles or Winghay Ironstone. It was formerly worked at Silverdale in the Hollywood pits, and there showed the following section:—

	Ft.	Ins.
Black shale, with chance bands of ironstone	1	3
Grey shale	0	4
Ironstone	1	0
Grey shale, with nodules of ironstone	0	8
Ironstone	0	6
Grey shale		

[1] 'Iron Ores of Great Britain,' Part iv, *Mem. Geol. Survey*, 1862, p. 275.

According to Smyth (*op. cit.* p. 275) the Gold Mine corresponds to the Priorsfield and Knowles Ironstone of Longton which are the leanest in the series.

Thick-band Ironstone.—This seam has not been worked, except in an isolated area.

Little Mine Ironstone.—The section at Kent's Lane is as follows[1]:—

	In.		In.
Nodules of ironstone	1–3½	Ironstone	3
Black shale	22	Black shale	2
Ironstone, lean	10	Ironstone	3
Shale	3		

This seam has been little worked. Smyth states that "the Little Mine and Brown Stone of the western side occur in the same portion of the measures as the Hanbury and the New Ironstone measures of Lane End (Longton). They are beds capable of producing generally 10 to 12 cwt. to the yard." (*op. cit.* p. 274-75.)

New Chalky Ironstone.—This seam is about 1 ft. 7 in. to 2 ft. thick, and according to Homer is similar in quality and character to the Chalky Ironstone. (*Trans. N. Staff. Inst. Eng.*, vol. 2, part 1, 1881, p. 22.)

Brown Mine Ironstone.—This seam has been extensively worked in the western district, but according to Homer (*op. cit.*) rarely exceeded 1 ft. in thickness in the syncline and was left. It is, however, of very good quality.

On the west the lower parts are often semi-blackband. The overlying coal is of poor quality but forms a good roof.[1]

Kent's Lane Colliery.

	Ft.	In.		Ft.	In.
Coal	4	0	Bass	0	5
Bass	3	0	Ironstone, Black-stone ...	0	8
Ironstone	0	8	Bass	0	6
Bass	0	6	Ironstone ... 4 ins. to	0	8
Ironstone	0	3			

New Mine Ironstone.—This stone is poor at Longton but 10 in. thick at Silverdale. At Longton the associated shales contain fish-remains in great number, forming a regular stratum. On the east, according to Homer, this seam, called the New Mine Ironstone, is 1 ft. 4 in. thick, lies immediately above the Burnwood ironstone, and was worked with it.

At Kent's Lane the stone is 9 in. with a coal below it 5 in. thick.

Knowles or Winghay Ironstone.—The ironstone of this name occurs usually in bands separated by shale, but only in the eastern area, its representative on the west being uncertain. It has been largely wrought at Fenton and Longton. No bed in the coalfield surpasses this in palæontological interest, the most striking feature being the remarkable assemblage of fishes.

[1] Cadman, J., *Trans. Inst. Min. Eng.*, vol. xxvi, 1905, p. 112.

"At Lane End (Longton) these stones are the leanest in the series. They would appear, from their position between the thick seams of coal called the Knowles and the Ash or Rowhurst, to correspond to the Gold Mine ironstone at Silverdale. The Knowles at Lane End is very batty, but turns out 15 cwt. to the yard."

"At Golden Hill Colliery the Knowles measures, after an interval of poverty near Shelton, appear to improve, and yield 10 in. of ironstone in 4 bands which are 2 ft. apart." (Iron Ores of Great Britain, p. 275.)

Priorsfield Ironstone.—This band lies about 35 ft. above the Knowles and was worked at Longton by opencast in a field held in ancient times by the Prior of Trentham. A small mollusc called *Carbonicola vinti* is found in this seam.

Rag Mine Ironstone.—Higher in the sequence comes a bed of ironstone known as the 'New Ironstone' or 'Rag Mine' which at Fenton occurs at a distance of 28 ft. above the Knowles rock and 49 yards above the Knowles Ironstone.[1] There is a band of hard black shale crammed with fossil fishes overlying the ironstone.

Chalky Mine Ironstone.—This stone is dark-brown to greyish-black in colour, with joints filled with carbonate of lime giving the seam the white appearance to which its name is due. It often contains minute crystals of zinc-blende, and at Lane End is much mixed with 'cement stone.' It varies in thickness from $1\frac{1}{2}$ ft. to $2\frac{1}{2}$ ft. At Shelton it is in 4 bands forming together a foot of stone; at Silverdale and Apedale it runs in 8 to 11 bands distributed in a thickness of shales varying from 6 to 8 yards. In these districts and also at Longton it has been extensively worked. The coal underlying the seam was sent to the surface for calcining the ironstone. The lower lean band of ironstone often assumes the appearance of a semi-blackband, but the upper bands remain unchanged.

At Lane End 'Longton' the ironstone formerly yielded about 12 cwts. to the square yard; at Silverdale and Apedale, where it is overlain by the Rusty Mine, as much as 2 tons to the yard, and at Hollywood 2,900 tons per acre. (Smyth, *op. cit.* p. 274.)

The section at Hollywood is as follows:—Ironstone, 4 in.; black shale, with chance bands of ironstone in the lower parts, 4 ft. 1 in.; ironstone 'Hussle-band,' 5 in.; black shale, 3 in.; ironstone, lean, 9 in.; coal, 2 ft. (Cadman, *op. cit.* p. 111.)

Rusty Mine Ironstone.—This seam has been little worked on the west of the coalfield. The joints of the ore are lined with hydrated oxide of iron, which imparts to it a rusty appearance.

The Pennystone ironstone of the eastern side of the coalfield lies at about the horizon of the Rusty Mine. It has been much worked and was largely used as a mixture with the Blackband Ironstones. (Cadman, *op. cit.*, p. 111.)

The Pennystone Ironstone.—The ironstones that occur somewhere about the horizon of the Pennystone of Shelton have received a variety of names: namely Rusty, Deep, Sheath and Blackstone in different districts.

[1] Ward, J., *Trans. N. Staffs. Inst. Min. Eng.*, vol. x, 1889–90, p. 50.

The Deep Mine at Longton was decidedly the richest and best ironstone, yielding 10 cwt. per square yard. (Iron Ores of Great Britain, p. 274.) It varies in colour from brown to greyish-black; is compact and homogeneous, and frequently crossed with veins containing a hydrated silicate of alumina and carbonate of lime. It also contains, at times, minute crystals of zinc-blende and copper pyrites. The seam is notable for the abundance in it of remains of fossil fishes.

The Pennystone at Shelton possesses similar characters to the Deep Mine, consisting of 20 in. of ironstone in three bands, the lowest of which is 10 to 12 in. thick. It is a brown, striped coarse-grain stone, with occasional laminæ of shale. The Deep Mine at Shelton also occurs in three bands 2, 3 and 4 in. thick.

The Pennystone is still worked at Shelton where upwards of 20,000 tons are got annually. It occurs in the form of discoid lumps in shale, containing about 69 per cent. of ferric oxide; or 48 per cent. of metallic iron.

Sheath Mine Ironstone.—This seam was extensively worked in the Silverdale area, where from 1½ to 2 ft. of ironstone lie in bands among 6 ft. of measures. Much refuse had to be sent out of the working-faces with the stone. This ironstone and the Black Stone according to Smyth produced at Apedale 17 cwt. to the square yard.

Sheath Mine Ironstone at Kent's Lane. (J. Cadman, *op. cit.*, p. 111.)

Roof.	Ft.	Ins.
Ironstone	0	3
Grey shale	0	2
Ironstone, Lean	0	11
Grey shale	0	2
Ironstone	0	3
Grey shale	0	8
Ironstone	0	4
Fireclay	3	4
Black Stone Ironstone seam	—	

Cannel Row Ironstone.—This stone is being worked at Goldenhill and Clanway, the annual output being about 10,000 tons.

At Clanway the stone, including a seam of cannel, is about 2 ft. thick. The section measured underground being:—

	Ft.	Ins.
Coal	2	0
Stone	0	10
Cannel	1	6
Stone	1	2
Coal	4	0

The cannel was once used for oil-making when it yielded according to Homer[1] from 50 to 60 gallons of crude oil of ·87 specific gravity per ton.

An analysis of the calcined unpicked ore according to Messrs. J. H. Ketley and Co. gives percentages of metallic iron, 57·90; phosphorus, 0·83; sulphur, 1·17; manganese, 1·83.

[1] *Journ. Iron and Steel Inst.*, 1875, p. 556.

Gubbin Mine Ironstone.—A valuable clayband seam from 1 ft. to 2 ft. 2 in. thick, lying in 3 ft. to 4 ft. of bass, which is being worked at Crackley and Goldendale, where it is in 3 or 4 bands 1 to 5 in. thick. In the Apedale area it is a dark-grey, compact stone, intersected with thin veins of carbonate of lime. It has not been worked extensively in this area, the lean ironstone-band being frequently inferior. The shale-partings are crowded with compressed specimens of *Anthracomya phillipsi* and *entomostraca.*

The following is the section at Goldenhill:—

	Ft.	Ins.
Top Ironstone	0	3½
Bass	1	0
Ironstone	0	4
Bass	0	2
Chatty Band Ironstone	0	2
Bass	1	6
Bottom Band Ironstone	0	4½

Cannel Mine Ironstone.—This seam is usually worked in conjunction with the Cannel Mine Coal. The ironstone is picked out from the fallen roof. The seam varies in quality and thickness. The stone is a black, dull, compact, argillaceous ironstone. There are six beds of nodules, together 12 in. thick; they are reputed to yield in Apedale about 18 cwt. to the square yard.

A section at Bassiloes is as follows:—

	Ft.	Ins.
Black bass	—	
Ironstone, Top band or Grit	0	10
Shale or bass	1	0
Ironstone, Flannel	0	2½
Shale or bass	0	2
Ironstone, Whet-stone	0	4
Shale or bass	1	0
Ironstone, Brown-band	0	2
Shale or bass	1	0
Ironstone, Blue-band	5 ins. to	0 8
Bass, with chance bands of ironstone	3	0
Cannel Mine coal seam	—	

Black-bass Ironstone.—This seam has not been worked to any great extent and where worked was removed from the top of the goaf. The thickness of the working was about 7 ft. and produced from 9 to 15 in. of ironstone.

The following section was taken at Apedale. (J. Cadman, *op. cit.*, p. 109.)

	Ft.	Ins.
Shale	—	
Ironstone	3 ins. to	0 6
Shale or bass	—	
Ironstone	0	1
Shale	0	3
Ironstone	0	2
Shale	1	3
Ironstone	0	1
Shale with nodules of ironstone	1	4
Ironstone	0	2½
Shale	1 ft. to	2 3

Blackband Ironstones.

In this series there are four principal bands known in descending order respectively as the Half-Yards or Blackband, the Red Shagg, the Red Mine and the Bassey or Pottery Bassey Mine. These names, however, are sometimes misapplied, as for instance the Bassey Mine is called the Red Mine in the Shelton district; while the Bassey Mine at Silverdale is the Half-Yards of Chesterton.

All the seams are more or less strongly banded in shades of brown and black, the banded appearance being due to bedding. These bands readily split, when the fractured surfaces are often seen to be crowded with either remains of stems and leaves of plants or of molluscan shells.

At the same time each band is said to possess characteristics by which it is identifiable. For instance the Red Shagg seldom contains shells although it is crowded with remnants of *Stigmaria ficoides*, whereas the Red Mine is less well laminated, contains few plant-remains, but an abundance of shells of *Anthracomya phillipsi*, a form which does not occur below the Cannel Row Coal. Normally the Bassey Mine is the most conspicuously banded rock, but it can not be separated by its fossil contents from the other seams, while the 'Half-Yards' contains a mixed assemblage of fossils, and its roof is crowded with stems of calamites.

In the calcined state the several seams also present distinctive characters; the 'Half-Yards' being flaky, the Red Mine solid and with a bluish bloom, while in the Red Shagg the original laminæ become separated and twisted. It is difficult, however, to distinguish the Bassey Mine from the Red Mine.

The outcrop of the Bassey Mine is shown on Plate II, p. 67, as a more or less continuous line from near Chesterton round the nose of the syncline at Golden Hill and thence east of Tunstall, Burslem and Hanley to Stoke-upon-Trent. There it is faulted, but it maintains a general trend of a little east of south as far as Longton where it is thrown down by the Florence Fault on the south and does not reappear.

The outcrop in the anticlinal region is discontinuous. It is displaced over a mile by the Apedale Fault, near Apedale, and trending thence south-westwards, it is again cut by several faults near Silverdale and, as proved in borings, thrown down to the south to a depth of over 1,500 ft.

Underground, the Bassey Mine appears to be continuous over the whole area but it deteriorates in places, especially near faults. In the anticlinal region the ironstones all change into limestones on the western side of the coalfield. The Bassey Mine attains its greatest richness and thickness in the south where it is now worked extensively near Fenton and Longton.

The 'Red Mines' include the 'Half-Yards,' the Red Shagg and the Red Mine. They cover a much smaller area than the underlying Bassey Mine. They have nowhere been found south of Stoke in the sinkings to the Bassey Mine Coal and Ironstone. The Red Mine is said to be represented at the Railway Pit, Berry Hill, but is not workable. These ores appear to die out

southwards. On the west they have been proved in the borehole near Keele and in underground workings, but still further west between Keele and Madeley they have passed into limestones.

In the Chatterley and High Carr areas they have been almost worked out but are still worked at New Hem Heath and Chesterton. In the area north of Newcastle-under-Lyme, bounded by the Apedale and Newcastle Faults, they have recently been proved by sinkings near Holditch, and also to the east of the Newcastle Fault near Wolstanton. But they are not likely to extend much further south than Newcastle judging by their southerly limit further east near Hanley.

Bassey Mine.—The Bassey or Pottery Bassey Mine is the lowest of the Blackband Ironstones, and at present the most important; its output being more than double that of any of the other seams. It lies at a distance of 110 ft. below the Red Mine in the anticlinal district, and of 250 ft. in the syncline on the eastern side of the coalfield (Plate III).

The seam is not so uniform as the others, and has a higher percentage of carbonaceous matter; the bottom stone is richer in iron than the top. It is thinner on the west than on the east of the district.

It extends much farther south than the 'Red Mines,' for it has been proved as far as Newstead about half-a-mile south-east of Trentham Station, and on the west, near Hanchurch. It occurs throughout the eastern area, but at Great Fenton is said to possess the character of the Red Shagg in addition to its own properties. In the anticlinal area it is feebly developed, and is there usually termed the Pottery Bassey Mine, to distinguish it from the Bassey Mine, a name that is sometimes applied to the seam that corresponds with the Half-Yards of Chesterton and Hanley, and the Red Mine of Apedale.

In thickness the bed is extremely variable. At Great Fenton on a working-face which was practically coincident with the strike, in the first 100 yards it varies from $4\frac{1}{2}$ ft. to $2\frac{3}{4}$ ft.; in the next 50 yards, from 3 ft. to 9 in.; the rest of the distance, from 9 in. to 2 ft. Along the dip the variation is similar. The top of the bed suffers more change than the base which maintains a fairly even lie. At Tunstall the basement-bed often contains seams of nodular ironstone which become separated from one another on calcining and for this reason is termed by the workmen the 'shotty' band. The nodules are composed of sphærosiderite and are about the size of small peas. Above the roof of the ironstone there is always present a band of poor nodular ironstone called cinder which lies in a bassy coal and often shows slickensided surfaces.

The stone varies in thickness from $1\frac{1}{2}$ to 6 ft. in the eastern district, and from 4 to 8 in. near Chesterton, Apedale and Silverdale. A good steam-raising coal ranging from 2 to 4 ft. thick almost everywhere underlies the seam.

In quality the stone maintains a uniformly good standard over the whole coalfield except sometimes near faults. During the war when labour became scarce it was impossible to select the ore and there was a general lowering of the percentage of iron from 50 to 44.

The following are details of the seam:—

Norton Area.

(Mr. A. R. Sawyer, 'Accidents in Mines,' 8vo, London, 1886.)

	Ft.	Ins.
Bass	0	9
Ironstone (lean)	1	1
Bass	0	9
Ironstone	1	4
Bass	1	0
Ironstone ... ... 8 ins. to	3	7
Coal ... ... 9 ins. to	1	6
Shale	1	6

Kidsgrove Area.

(Mr. A. R. Sawyer, *op. cit.*)

	Ft.	Ins.
Bass	0	6
Ironstone, Tops	?	
Ironstone, Peel (lean)	1	6
Cannel	0	4
Brazils	0	8
Dirt	0	3
Coal	0	6
Dirt	0	10
Coal ... ... 1 ft. to	1	6

Grange Colliery, Cobridge.

(From Mr. J. H. Cole.)

	Ft.	Ins.
Ironstone	1	6
Coal	1	3
Ironstone	4	10
Coal	0	5

Forge Pits, Chesterton.

(Midland Coal, Coke and Iron Co.)

	Ft.	Ins.
Ironstone ... ... 4 ins. to	0	8
Coal ... ... 3 ft. to	4	0

Big Pit, near Tunstall.

(The Goldenhill Colliery Co.)

	Ft.	Ins.
Top ironstone	1	0
Bass	0	10
Ironstone	1	3
Bass	2	9
Ironstone	0	9
Curly band ironstone (shotty stone)	0	4
Coal	0	9
Fireclay	—	

Great Fenton.

(From Mr. G. Mitcheson.)

	Ft.	Ins.
Cinder	—	
Bass	0	6
Roof-stone ... ... 6 ins. to	0	9
Bass	0	2
Ironstone ... ... up to	6	0
Bassey Mine Coal	2	2
Fireclay	—	

Red Mine.—This seam is normally the richest of the Blackband ironstones. Its distribution is similar to that of the Half-Yards and Red Shagg and like them it changes into limestone westwards. Southwards it dies out. It lies about 60 ft. below the Red Shagg at Silverdale and at 80 ft. near Shelton.

In the western district the seam varies in thickness from 1 to 14 ft. and when thick has a 6-in. seam of coal running in the middle of it. The bottom-stone is the best part. At Chesterton the ironstone is from 2 to $3\frac{1}{2}$ ft. thick but there is another 2 ft. of lower grade ironstone immediately above it. At the Forge pits the top-stone is $2\frac{1}{4}$ ft. thick and the bottom-stone from 2 to $3\frac{1}{2}$ ft. In the Knutton Manor area the thickness varies from $2\frac{1}{2}$ to $5\frac{1}{2}$ ft.

In the eastern (synclinal) area the seam varies from 2 to 4 ft. in thickness and is not divided by a coal. Here it has a moderately good roof of bass, containing several small bands of argillaceous ironstone and a band of oil-shale, $1\frac{1}{2}$ ft. thick, yielding 28 gallons of oil per ton. After the oil has been extracted the residue contains from 3 to 5 tons of good blast-furnace mine to every ton of oil made.

Above this oil-shale are several beds with curious local names, given in the subjoined section. The 'flannels' consist almost entirely of the remains of *Anthracomya phillipsi*. Below the ironstone there is a coal of moderate quality and about 2 ft. thick, resting on a fireclay floor which heaves when wet.

The Red Mine is being worked at Chesterton, Goldendale, and Cobridge on the east and at Silverdale and Knutton Manor on the west of the coalfield.

It will be seen from the analyses given on p. 84 that this is the richest seam of the Blackband ironstones, the percentage of ferrous oxide in the raw stone being upwards of 50. Phosphoric acid ranges from ·51 to ·65; while combined water, organic matter and carbon dioxide range from 40 to 50 per cent.

The following sections show the varying thickness of the Red Mine Stone:—

Silverdale.

(J. Cadman, *Trans. Fed. Inst. Min. Eng.*, vol. xxii, 1901, p. 98.)

	Ft.	In.
Argillaceous sandstone, ...2 ft. to	30	0
Shale ... ... nil to	3	6
Isaacs, inferior ironstone	0	3
Flannels	0	4
Ironstone	0	4
Flannels	0	3
Ironstone, tops	2	0
Ironstone, middles ... ... 1 ft. to	1	6
Ironstone, bottoms ... ... nil to	3	0
Coal ... ... 1 ft. to	1	6

Norton.

(A. R. Sawyer, 'Accidents in Mines.')

	Ft.
Argillaceous sandstone	1¼ to 1½
Marl	nil to 4
Isaacs	⅓
Flannels	⅓ to ½
Ironstone tops	1
Oil-shale	¾
Ironstone bottoms	10 in. to 2 ft.
Coal	20 in. to 2 ft.

Kidsgrove.

(A. R. Sawyer, 'Accidents in Mines.')

	Ft.
Coal	1
Argillaceous sandstone	?
Marl and lean stone	¼
Flannels	½
Grates, Jacobs and Isaacs	1
Oil-shale and lean ironstone	10 in.
Ironstone	nil to 4 ft.
Coal	1 to 1½

Red Shagg Ironstone.—This is the second true 'blackband' ironstone encountered in sinkings. In the anticlinal area it lies about 36 ft. below the 'Half-Yards' and 45 ft. below it in the synclinal district. It covers approximately the same area as the Half-Yards and suffers the same change into limestone on the west of the anticlinal region, and also dies out south of Stoke. Its southerly extent on the west is unknown.

In the neighbourhood of Hanley this bed lies immediately upon a bed of coal and is 15-17 in. thick, whereas on the west at Silverdale it varies from 9 in. to 7 ft. It exhibits numerous bedding laminæ which, on cross-fracture, show many brown and black stripes generally from $\frac{1}{20}$ to $\frac{1}{4}$ of an inch in thickness.

Immediately below the Red Shagg there is an inferior coal about 1 to 2½ ft. thick with joints filled in with smutty coal. Below this is soft fire-clay, 6 ft. thick, which gives trouble by swelling when wet. The roof is sometimes formed by a seam of lean ironstone called 'grates'; it is of variable thickness and is often found occurring in two bands termed 'red' and 'black' grates. A seam of bass is sometimes found, about 1½ ft. thick, which yields 12-15 gallons of heavy oil to the ton.

Like other blackbands the Red Shagg needs no coal for its calcination, but the loss on calcination is less than in other seams. It is of excellent quality containing from 36-46 per cent. of ferrous oxide; 0·5 to 0·99 phosphorus pentoxide and a trace to 2·15 sulphuric acid.

In the Chesterton district the thickness ranges from 2 to 4 ft.; around Hanley and Cobridge from 3 to 3½ ft., at Shelton 2 ft., while it varies from 1½ to 5 ft. in the Silverdale and Knutton areas. The bottom stone is often of richer quality than

the top stone. The following sections illustrate the variations in thickness:—

Silverdale

(J. Cadman, *op. cit.*, p. 97).

	Ft.	In.
Grits	nil to 0	9
Clod	2 ft. to 3	0
Red and black grates	6 in. to 1	6
Ironstone	1 ft. 6 in. to 5	0
Coal	14 in. to 1	8
Fire-clay	—	—

Norton.

(A. R. Sawyer, 'Accidents in Mines.')

	Ft.	In.
Cossil, lean	0	6
Bass	7 in. to 1	2
Cannel bass	nil to 0	6
Ironstone	14 in. to 6	0
Coal	2	0
Fire-clay	—	—

Kidsgrove

(A. R. Sawyer, 'Accidents in Mines.')

	Ft.	In.
Coal	2	0
Clod	2 ft. to 3	0
Grates	3 in. to 0	6
Ironstone, tops	1	8
Ironstone, bottoms	14 in. to 4	6
Fire-clay	—	—

The Red Shagg is being largely worked over the northern part of the synclinal area, and in the anticlinal district near Apedale, Knutton and Silverdale.

The Half-Yards or Blackband Ironstone.—This is the top seam of the true Blackband ironstones. In the Silverdale district it is called the Bassey Mine, while the true Bassey Mine is described by the name 'Pottery Bassey Mine.'

In the centre of the coal basin, as near Tunstall and Chatterley, it lies in one bed varying in thickness from $1\frac{1}{2}$ to 5 ft., and is of first-class quality. There is a seam of good steam-coal, 1 to $2\frac{1}{2}$ ft. thick, immediately below it, and it has been noticed by the miners that where the ironstone is thick the coal is thin and *vice versa*. The roof of the Half-Yards here contains several small bands of argillaceous ironstone, but these are not being worked.

In the Silverdale district the 'Half-Yards' or 'Bassey' Ironstone varies in thickness from 9 in. to 6 ft. It is in this neighbourhood rather more laminated than the other seams and of a somewhat darker colour. The roof is a black shale containing bands of argillaceous ironstone, which readily parts from the blackband stone. Immediately below there is a good coal, 1-$2\frac{1}{2}$ ft. thick, lying on a soft black slickensided shale. In some parts of the district, notably in the west, a bed of coal or often of cannel, $\frac{1}{2}$-1 ft. thick, occurs above the ironstone.

The seam is practically worked out north of the 'Millbank' Fault but has been proved in the borehole near Keele Home Farm, south of the fault, at a depth of 1,395 ft., and also in underground workings farther west. There is thus reason for believing that the band extends under the area occupied by Keele Beds in this neighbourhood, but how far south it is impossible to say.

In the area between the Apedale and the Newcastle faults west of Wolstanton, a shaft has proved the occurrence of the Red Mines at a depth of 2,022 ft., while east of the Newcastle fault near Wolstanton another borehole has penetrated them.

Several collieries both on the east and west of the coalfield are raising this seam. It is worked at Silverdale and Knutton Manor, at the Forge pits and at New Hem Heath near Chesterton; at Goldendale, Tunstall. The Red Mines are practically worked out near Hanley, in the area between the outcrop of the Twist Coal and the Bradwell Wood Fault, and also near Crackley and at Silverdale north of the Millbank Fault.

In the workings a little way south of Etruria Station the seam is of exceptionally poor quality. On the west of the coalfield at Halmer's End and at Madeley Wood the ironstone is said to pass laterally into limestone.

The uncalcined stone contains from 35 to 50 per cent. of ferrous oxide; from 0·6 to 0·8 of phosphorus pentoxide; from a trace to 1·7 of sulphuric acid and up to 46 per cent. of organic matter, carbon dioxide and moisture.

The following sections indicate the thickness of the seam in various districts:—

Silverdale

(from J. Cadman, *op. cit.*).

	Ft.	Ins.
Loose shale	1	0
Strong black bass	1 ft. to 1	4
Coal and cannel	nil to 0	9
Ironstone	1 ft. to 3	0
Coal	1	6
Warrant	0	4
Coal	0	6
Alum-shale	—	—

Norton

(from A. R. Sawyer, *op. cit.*).

	Ft.	In.
Shale	—	—
Bass	0	6
Boring band	0	4
Bass	1	3
Ironstone	1 ft. to 1	2
Coal	1	8
Alum-shale	—	—

Kidsgrove

(from A. R. Sawyer, *op. cit.*).

	Ft.	In.
Black bass containing oil	2	3
Ironstone, tops	6 in. to 0	10
Ironstone, bottoms	nil to 6	0
Coal	4 in. to 2	0
Alum-shale	1 ft. to 1	6

Cheadle and Shaffalong Coalfields.

In these coalfields the measures which contain the ironstones in the Pottery Coalfield are absent, but a bed, known as the Froghall Hæmatite, is found at the base of the Coal Measures, in the northern part.

This seam of ironstone "lies either directly on the First Grit or may be separated from it by as much as 15 ft. of shale. With the exception of a few patches that are worked for making red paint, the seam has been practically worked out. It was deposited in the form of an extremely thin lenticle of somewhat irregular thickness, which was roughly elliptical, the long axis of the ellipse trending east and west. The southern limit has been proved at the west end by borings in the Consall Valley, near the stream flowing north from Kingsley Moor. It was followed till it was too thin to work both at Hazlescross Pits, and at some pits close to Kingsley Village. A boring proved its southern termination again at Froghall, and only a trace of it was met with at Whiston. To the east of Ipstones it passes to a curious admixture of coal and ironstone, which did not pay to work. Beyond this for some considerable distance the limit to the north is the natural outcrop, but close to the Churnet it has been proved to die away to a few inches before reaching the outcrop. In order to prove if this seam came on again a boring was put down by Mr. Almond from the bottom of Park Hall Pit, and this corroborated the evidence already given that the seam does not extend south of the line described above."

"That this seam owed its existence to local conditions, which tended to recur, seems to be shown by the fact that in the area where the seams become a mixture of coal and ironstone two other similar admixtures occur between the First and Third Grits. This association suggests some special condition for its occurrence, and it seems that filtration may be partly the cause."[1]

This seam has been extensively worked, and since statistics were first published in 1857 many millions of tons have been raised.

In the period 1857-1869 the total output was 5,407,537 tons, equal to a yearly average of 415,964 tons. From 1870-1881 the output fell to a total of 555,363 tons, or an annual average of 46,280 tons. Since that date only a small quantity has been raised; the present output being less than 1,000 tons per annum, and that entirely of stone raised for making red paint.

Near the outcrop the ironstone was porous and easily worked in the furnace, but under cover it became black and hard and contained much sulphur, and Smyth[2] states that the "ironstone itself when well-developed is of a brownish sometimes blackish colour, often striated in the direction of the planes of bedding, 18 to 22 in. thick, and divided by occasional joints lined with calc-spar. On the western bank of the Churnet it assumes a bright red colour, and much the appearance of a somewhat earthy hæmatite." He gives the analysis quoted on p. 83. The second analysis was made recently of ore from Froghall.

[1] 'The Geology of the Cheadle Coalfield,' *Mem. Geol. Surv.*, 1903, pp. 18, 19.
[2] 'Iron Ores of Great Britain,' Pt. iv, *Mem. Geol. Surv.*, 1862, pp. 276–278.

In the Shaffalong Coalfield search has been made for this bed. A sinking was put down at Westwood Manor.[1] "Here the ore has more the character of a red hæmatite than a brown hæmatite." No further development has apparently taken place.

Ore from Froghall, near Cheadle.[2]

Ore dried at 100° C.—	
Peroxide of iron	52·85
Protoxide of manganese	0·81
Lime	14·61
Magnesia	5·70
Carbonic acid	18·14
Phosphoric acid	0·32
Sulphuric acid	0·28
Silica	trace
Water	4·75
Organic matter	1·30
Ignited insoluble residue	0·04
	98·78
Iron, total amount	36·98

The following analysis is supplied by the Midland Coal, Coke and Iron Company, Limited.

Ore from Froghall (state as received).

Iron (metallic)	46·30
Manganese	0·50
Phosphorus	0·14
Oxygen	20·04
Combined water, CO_2, etc.	15·90
Moisture (hygroscopic)	0·30
Lime	9·06
Magnesia	3·59
Alumina	2·10
Silica (pure)	1·93
T. sulphur	0·07
Ferrous oxide	1·16
Ferric oxide	64·86

References.

1875 Homer, C. J. The North Staffordshire Coalfield with the Ironstones contained therein. *Journ. Iron and Steel Institute*, p. 540.
1886 Sawyer, A. R. Accidents in Mines. 8vo. London.
1889 Ward, J. The Lower Coal Measures of the Cheadle Coalfield, with special reference to the recent boring for Ironstones at Park Hill Colliery. *Trans. N. Staffs. Nat. Field Club*, p. 88.
1890 ———The Geological Features of the North Staffordshire Coalfields. *Trans. N. Staffs. Min. Eng.*, vol. x, pp. 1–189.
1893 Kendall, J. D. The Iron Ores of Great Britain and Ireland. 8vo. London.
1901 Cadman, J. The occurrence, mode of working and treatment of the Ironstones found in the North Staffordshire Coalfield. *Trans. Fed. Inst. Min. Eng.*, vol. xxii, p. 89 and *ibid.* vol. xxvi, 1903, pp. 106–119.

Publications of the Geological Survey.

Memoirs.—Iron Ores of Great Britain, Pt. iv, 1862. The Geology of the Cheadle Coalfield, 1903. The Geology of the North Staffordshire Coalfields, 1905.
Maps.—Six-inch, Staffordshire, 11, 12, 17, 18, 19 N.E., 19 S.E.

[1] Louis ('Report on Iron,' etc., *Dept. of Scient. and Industrial Research*, 2nd edit., 1918, p. 28).
[2] 'Iron Ores of Great Britain,' Pt. iv, *Mem. Geol. Surv.*, 1862, p. 291.

Analyses of the Bassey Mine Ironstone, North Staffordshire.

Percentage results. Figures in italics are percentages of Ignited Insoluble Residue.

	(1)	(2)	(3)	(4)	(5)	(6)
Ferrous oxide	41·65	10·28	6·43	3·08	45·53	49·50
Ferric oxide	1·14	66·80	63·84	68·42	5·00	—
Manganous oxide ...	1·58	—	—	—	1·74	1·71
Manganic oxide ...	—	2·41	2·03	1·14	—	—
Alumina	1·42	2·16	5·00	4·40	0·32	0·45
Lime	4·20	4·80	5·40	5·50	2·91	2·23
Magnesia	2·16	2·63	1·10	1·60	2·13	1·94
Carbon dioxide ...	30·55	—	—	—	32·12	35·21
Phosphoric acid ...	0·65	1·29	1·56	1·19	0·86	0·51
Sulphuric acid ...	0·89	2·26	2·04	2·51	0·08	—
Iron pyrites	—	—	—	—	0·37	—
Water at 100° C. ...	—	—	—	—	0·48	—
Water, combined ...	—	—	2·00	1·42	1·81	0·60
Organic matter ...	12·70	—	—	—	5·20	7·10
Ignited insoluble residue	—	—	—	—	1·95	—
Silica	3·30	7·40	10·24	10·70	*1·36*	0·27
Alumina	—	—	—	—	*0·42*	—
Ferric oxide ...	—	—	—	—	*0·06*	—
Potash	—	—	—	—	*0·05*	—
Metallic iron	33·20	54·76	49·68	50·28	39·13	38·71

(1) Raw stone, (2) Calcined, Great Fenton, from the Stafford Coal and Iron Company. (3) and (4) Calcined ore, Longton district, Shelton Iron, Steel and Coal Company. (5) Mixed stone from Longton, Hanley and Apedale, 'Iron Ores, Pt. iv, *Mem. Geol. Surv.*, 1862, pp. 284–85. (6) Raw stone, Chatterley, C. J. Homer, *Journ. Iron and Steel Inst.*, 1875, p. 562. An analysis of the Pottery Bassey Mine of Apedale furnished by the Midland Coal, Coke and Iron Company gives for the calcined ore: metallic iron, 36·60; lime, 16·48; silica, 11·86; phosphorus, 0·86; sulphides and sulphates, 4·31.

Analyses of the Red Mine Ironstone, North Staffordshire.

Percentage results, as above.

	(1)	(2)	(3)	(4)	(5)
Ferrous oxide	50·73	39·70	39·89	50·90	—
Ferric oxide	0·45	2·41	15·40	—	92·52
Manganous oxide	1·86	1·10	1·26	1·76	2·44 (MnO_2)
Alumina	0·26	0·51	1·00	0·73	0·59
Lime	2·52	3·02	2·24	2·07	1·29
Magnesia	1·26	2·41	1·01	0·80	0·94
Carbon dioxide	33·39	—	—	33·02	—
Phosphoric acid	0·73	0·60	0·54	0·62	0·93
Sulphuric acid	0·08	—	—	—	—
Iron pyrites	0·30	—	—	0·10	—
Water at 100° C. ... ... }	undet.	—	—	—	—
Water, combined ... }		—	—	0·12	—
Organic matter	6·41	—	—	8·75	—
Loss on ignition	—	46·59	39·27	—	—
Ignited insoluble residu ...	0·72	—	—	—	—
Silica	*0·38*	4·07	0·51	1·13	0·79
Alumina	*0·32*	—	—	—	—
Lime	*0·03*	—	—	—	—
Potash	*0·14*	—	—	—	—
Metallic iron	39·84	32·56	41·80	39·58	64·77

(1) Raw stone from Apedale, 'Iron Ores of Great Britain, Pt. iv, *Mem. Geol. Surv.*, 1862, p. 283. (2) Middle stone (raw). (3) Bottom stone (raw), Silverdale, J. Cadman, *Trans. Fed. Inst. Min. Eng.*, vol. xxii, 1901, p. 99. (4) Raw stone, from Chatterley. (5) Calcined stone from Chatterley, C. J. Homer, *Journ. Iron and Steel Inst.*, 1875, p. 562.

Analyses supplied by the Midland Coal, Coke and Iron Company, of the Red Mine stone from the Forge Pits, give for the top stone (raw): metallic iron, 26·80 per cent.; for the bottom stone (raw), 39·40 per cent metallic iron.

Analyses of 'Lean Mine' Ironstones, North Staffordshire.

Percentage results. Figures in italics are percentages of Ignited Insoluble Residue.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Ferrous oxide	41·80	38·85	6·94	46·35	48·33	51·07	58·46	—	48·59	30·82	2·57	44·03	39·70	36·81	41·15	34·87	26·34
Ferric oxide	—	—	60·66	3·00	—	—	—	98·28	—	1·43	49·10	1·11	0·80	1·77	1·84	2·15	0·40
Manganous oxide	2·16	2·04	0·85	1·61	2·99	2·36	0·01	0·02	1·43	1·24	1·70	2·92	1·00	1·93	1·40	2·39	2·69
Alumina	0·53	5·71	7·00	0·30	0·41	0·54	—	—	4·18	7·51	10·18	2·00	0·20	1·70	0·60	0·84	3·00
Lime	5·07	2·52	4·60	1·93	1·52	1·74	2·65	0·74	1·66	1·24	2·20	3·67	1·61	2·33	4·00	4·39	3·11
Magnesia	3·03	1·13	1·02	2·24	1·19	1·10	1·02	0·27	1·38	0·49	1·26	2·80	0·60	1·70	1·65	2·70	1·79
Carbon dioxide	32·40	28·24	—	32·46	32·76	33·63	34·65	—	31·57	24·78	1·80	—	—	—	—	—	—
Phosphoric acid	1·40	2·76	1·13	0·67	0·87	1·12	0·40	0·59	0·998	0·78	1·03	0·69	0·67	0·44	1·82	0·97	0·63
Sulphuric acid	trace.	—	1·36	trace.	trace.	trace.	—	—	0·219	0·42	0·72	0·50	0·17	0·49	0·31	trace.	0·47
Iron pyrites	0·04	0·80	—	0·15	0·19	0·17	1·62	—	—	moisture	moisture	—	—	—	—	—	—
Water at 100° C.	0·36	—	—	0·14	—	—	—	—	—	2·00	7·24	—	—	—	—	—	—
Water, combined	0·71	3·25	—	0·66	0·85	0·99	0·13	—	—	—	—	—	—	—	—	—	—
Organic matter	0·79	4·20	—	2·95	1·17	1·24	0·61	—	2·60	14·36	—	—	—	—	—	—	—
Loss on ignition	—	—	1·29	—	—	—	—	—	—	—	—	37·84	32·51	29·29	33·84	35·60	30·36
Ignited insoluble residue ...	10·81	—	—	7·29	9·28	5·18	—	—	—	—	—	—	—	—	—	—	—
Silica	*7·32*	10·50	15·10	*5·78*	*6·25*	*3·02*	0·08	0·10	6·40	14·79	22·12	5·00	22·46	23·50	13·80	16·56	31·00
Alumina	*3·28*	—	—	*1·22*	*2·41*	*1·93*	—	—	—	—	—	—	—	—	—	—	—
Ferric oxide	*0·20*	—	—	*0·11*	*0·21*	*0·12*	—	—	—	—	—	—	—	—	—	—	—
Lime	*0·04*	—	—	—	—	—	—	0·74	—	—	—	—	—	—	—	—	—
Magnesia...	*trace.*	—	—	—	—	—	—	0·27	—	—	—	—	—	—	—	—	—
Potash	*0·09*	—	—	*0·18*	*0·22*	*0·28*	—	—	—	—	—	—	—	—	—	—	—
Metallic iron	32·64	30·60	47·85	38·29	37·83	39·88	46·51	68·80	37·79	24·97	36·36	35·03	31·44	29·86	33·29	28·63	20·77

(1) Cannel Mine (raw stone), Apedale, 'Iron Ores of Great Britain,' part iv, *Mem. Geol. Surv.*, 1862, p. 286. (2) Gubbin (raw stone), Chatterley, C. J. Homer, *Journ. Iron and Steel Inst.*, 1875, p. 562. (3) Pennystone (calcined), average, Shelton, Shelton Iron, Steel and Coal Company. (4) Pennystone (raw stone). Shelton, 'Iron Ores,' *op. cit.*, p. 287. (5) Deep Mine (raw), Longton, Shelton and Apedale 'Iron Ores,' *op. cit.*, pp. 288—289. (6) Chalky Mine (raw), Foley and Shelton, 'Iron Ores,' *op. cit.*, pp. 289—290. (7) Winghay (raw), and (8) (calcined), Chatterley, Homer, *op. cit.*, p. 562. (9) Burnwood (raw), Fenton, Stafford Coal and Iron Company. (10) Burnwood (raw), and (11) do. (calcined), Newchapel, R. Heath and Sons. (12) Sheath Mine (calcined), Kents Lane, J. Cadman, *Trans. Fed. Inst. Min. Eng.*, vol. xxvi, 1903, p. 114. (13) Chalky Mine (tops, raw), Kents Lane, Cadman, *op. cit.*, p. 114. (14) Chalky Mine (bottoms, raw), Hollywood, Cadman, *op. cit.*, p. 114. (15) Brown Mine (raw), Hollywood, Cadman, *op. cit.*, p. 114. (16) Gold Mine (raw), Hollywood, Cadman, *op. cit.*, p. 114. (17) Top Two Row (raw), Nabbs, Cadman, *op. cit.*, p. 114.

Analyses of the Red Shagg Ironstone, North Staffordshire.

Percentage results, as above.

	(1)	(2)	(3)	(4)
Ferrous oxide	46·53	42·95	45·32	—
Ferric oxide	—	3·29	—	91·50
Manganous oxide	2·54	2·50	2·23	—
Manganic oxide	—	—	—	4·12
Alumina	0·97	1·20	0·32	0·55
Lime	2·41	2·34	0·64	1·10
Magnesia	1·39	1·34	0·20	0·34
Carbon dioxide	30·77	—	29·92	—
Phosphoric acid	0·69	0·51	0·99	1·53
Sulphuric acid	0·04	0·28	—	—
Iron pyrites	0·34	—	0·32	—
Water at 100° C.	1·47	—	—	—
Water combined	—	—	1·07	—
Organic matter	10·46	—	18·60	—
Loss on ignition	—	43·45	—	—
Ignited insoluble residue	2·27	—	—	—
Silica	*1·93*	2·00	0·50	0·86
Alumina	*0·25*	—	—	—
Ferric oxide	*0·05*	—	—	—
Lime	*0·03*	—	—	—
Potash	*0·20*	—	—	—
Metallic iron	36·39	35·17	35·40	64·05

(1) Raw stone from Shelton, Hanley and Apedale, 'Iron Ores of Great Britain,' Pt. iv, *Mem. Geol. Surv.*, 1862, pp. 279. (2) Raw stone, Silverdale, J. Cadman, *Trans. Fed. Inst. Min. Eng.*, vol. xxii, 1901, p. 99. (3) Raw stone. (4) Calcined stone, Chatterley, C. J. Homer, *Journ. Iron and Steel Inst.*, 1875, p. 562.

An average of many analyses by the Midland Coal, Coke and Iron Company gives 38·80 per cent metallic iron for the raw stone of the Forge Pits, Chesterton.

Analyses of the Half-Yard or Black-band Ironstone.

Percentage results.

	(1)	(2)	(3)
Ferrous oxide	41·87	50·27	—
Ferric oxide	2·65	—	92·57
Manganous oxide	1·70	1·06	—
Manganic oxide	—	—	2·55
Alumina	1·45	0·20	0·28
Lime	3·00	0·53	0·67
Magnesia	1·08	0·25	0·13
Carbon dioxide	—	32·07	—
Phosphoric acid	0·61	0·83	1·24
Sulphuric acid	trace	—	—
Silica	2·20	0·15	2·50
Iron pyrites	—	trace	0·06
Water, combined	—	3·74	—
Organic matter	—	10·90	—
Loss on ignition	46·05	—	—
Metallic iron	34·42	39·10	64·80

(1) Raw stone, Silverdale, J. Cadman, *Trans. Fed. Inst. Min. Eng.*, vol. xxii, 1901, p. 99. (2) Raw stone, Chatterley, and (3) calcined ore, C. J. Homer, *Journ. Iron and Steel Inst.*, 1875, p. 562.

The raw stone from the Forge Pits gave on an analysis for the Midland Coal Coke and Iron Company, 37 per cent. metallic iron.

Analyses of mixed Red Mines Ironstones, North Staffordshire.

Percentage results.

	(1)	(2)	(3)	(4)	(5)
Ferrous oxide	43·85	5·14	36·78	3·86	1·28
Ferric oxide	1·29	73·16	2·86	69·96	71·52
Manganous oxide	2·46	—	1·69	—	—
Manganic oxide	—	3·63	—	2·86	2·00
Alumina	0·90	1·20	2·20	3·74	3·80
Lime	4·00	5·30	3·20	5·43	5·60
Magnesia	1·30	1·38	1·26	2·14	0·84
Phosphoric acid	1·37	2·06	0·82	1·40	1·78
Sulphuric acid	0·75	1·00	1·25	2·12	2·04
Silica	3·00	4·50	2·60	4·42	9·50
Water at 100° C.	0·40	—	4·20	2·00	—
Water, combined	—	1·50			
					Loss on ignition
Carbon dioxide	30·57	1·00	43·20	2·00	1·50
Organic matter	10·08				
Metallic iron	35·00	55·20	30·60	51·96	51·05

(1) Raw stone and (2) calcined ore, Chesterton, from Robert Heath and Sons. (3) Raw stone and (4) calcined ore, Grange pits, from Robert Heath and Sons. (5) Calcined ore, New Hem Heath, from the Shelton Iron, Steel and Coal Company.

CHAPTER VII.

CARBONIFEROUS BEDDED ORES (*contd.*).

Shropshire.

By H. Dewey.

General Account.

Coalbrookdale is the only coalfield in Shropshire where ironstone is still being raised. Most of the western and central parts are exhausted, the active mines being situated between St. George's and Madeley Wood on the eastern side of the coalfield (Fig. 9, p. 88). Within the area thus circumscribed the Coal Measures attain their maximum thickness of 1,200 ft. at the northern end; in the south some of the lower productive beds were eroded away before the upper, barren, measures were deposited. (*See* Vertical Sections on p. 89). All the known useful beds of ironstone occur in the lower fourth part of the productive measures.

The sequence of ironstones and coal-seams is given in Fig. 10, p. 89. The ironstones occur in the form of nodules sometimes coalescing into 'beds.' They all consist of carbonate of iron and are imbedded in clays or shales, with the exception of the Crawstone which forms ill-defined masses in a fine-grained sandstone.

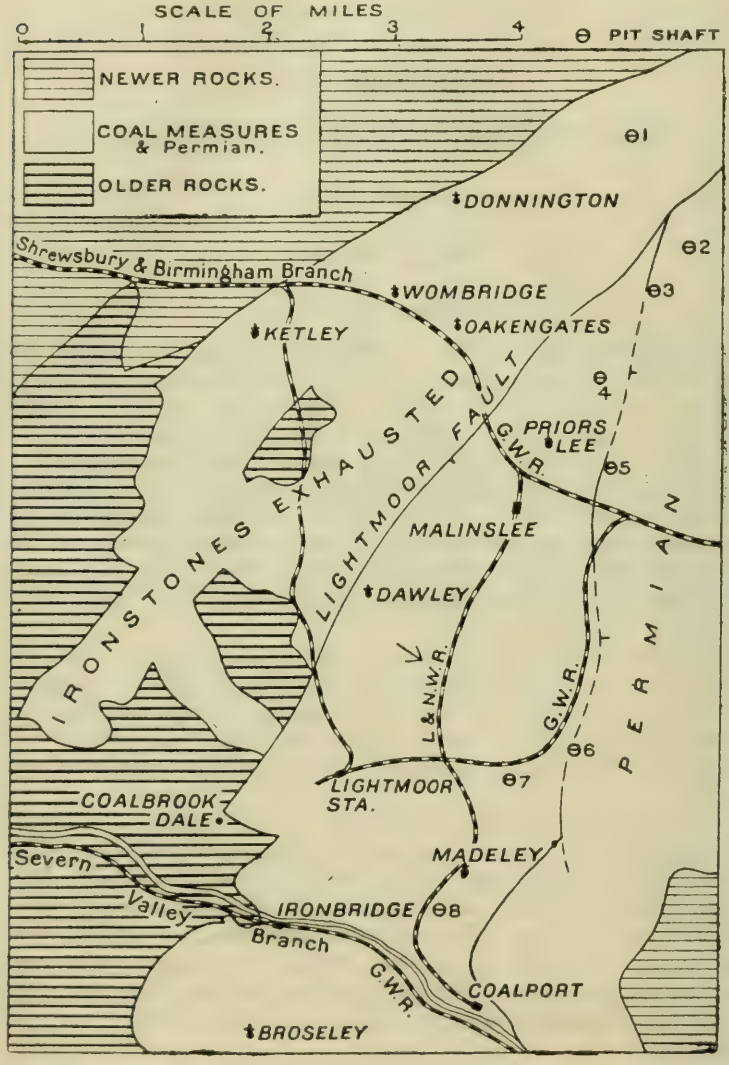
In chemical composition they vary but slightly. Metallic iron ranges from 35 to 40 per cent.; phosphoric acid from ·23 to ·79; sulphuric acid from a trace to ·11; and lime from 2·3 to 3·11 per cent. The loss of weight on calcination is about 25 per cent. of the raw stone. For complete analyses, *see* pp. 92, 93.

In recent years the output has fallen off greatly. For many years it was upwards of 300,000 tons per annum, but since 1888 has rapidly decreased and is at present only a little over 3,000 tons a year.

Coalbrookdale is intimately associated with the early history of the manufacture of pig-iron. When the exhaustion of woodlands was threatened in the early years of the eighteenth century attention was turned to the application of coal in the blast furnaces. About 1730 an unsuccessful attempt was made by Abraham Darby to smelt iron with a mixture of raw coal and charcoal. He, however, made further trials and finally treated pit-coal as charcoal-burners treat wood, and with the coke so produced he finally succeeded.[1] The success of this experiment led to a great increase in the quantity of pig-iron made. Shropshire was then, and for long after, the principal iron-

[1] Percy, 'Metallurgy,' Iron and Steel, 1864, p. 888. Smiles, 'Industrial Biography,' 1876, pp. 77–98.

FIG. 9.—*Geological Sketch-map of the Coalbrookdale Coalfield.*



1. Freehold.
2. Granville.
3. Grange.
4. Woodhouse.
5. Stafford.
6. Kemberton.
7. Halesfield.
8. Blists Hill.

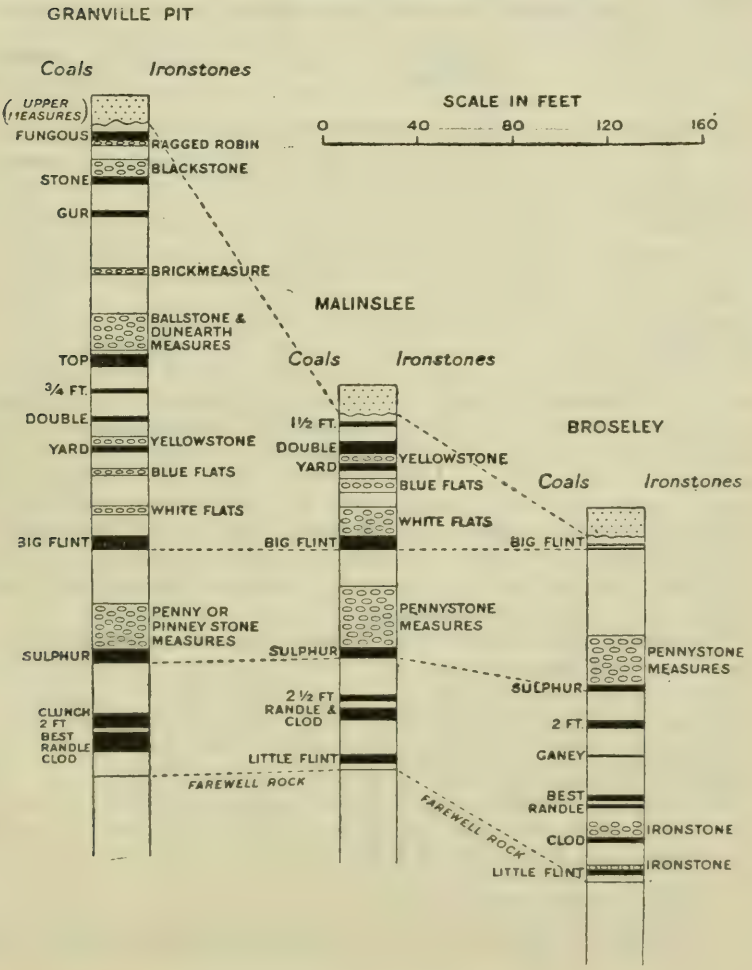
manufacturing county as is indicated by the following figures:—In the year 1740 the total production of pig-iron in England and Wales was 17,350 tons, of which 2,100 tons, or 12 per cent., were made in Shropshire. In 1788 Shropshire produced 40 per cent. of the iron made, but after that year, although its output greatly increased, the percentage fell by reason of the many new furnaces which were built in other parts of Great Britain. In 1796 its output was 25 per cent.; in 1806, 20 per cent., and since then it

has further declined. Its maximum output was in 1869 when it reached 197,443 tons. The last official figures gave 40,000 tons in 1903, since when the figures for Shropshire have been included with Staffordshire.

No less intimately connected with Shropshire were the discoveries made in methods of treating iron. In 1766 'puddling,' or the conversion of pig-iron into malleable or 'bar' iron by means of the reverberatory furnace, was first carried out, and a patent granted to the Craneges of Coalbrookdale. Later on Cort first systematically conducted the process of drawing out the puddled lumps through grooved rolls, while at Ketley the first iron railway was laid down.

Abraham Darby, Senior, also led the way in his discovery of making cast-iron utensils by means of sand-moulds, all previous

FIG. 10.—*General Sections of the Ironstone Measures of the Coalbrookdale Coalfield.*



attempts having failed on account of the moulds having been made of clay. Lastly, the first iron-bridge ever made was constructed by Darby's grandson in 1788, namely, that bridge which still spans the Severn at Ironbridge.

In calculating reserves attention must be paid to the fact that the higher seams disappear in the centre and south. The Chance Pennystone, the Ragged Robins and the Blackstone are the first to go; then the Brick-measure, the Ballstone and the Yellowstone; next the Blue Flats and the White Flats, so that at Broseley only the Pennystone and Crawstone are found, and to the south of Broseley the Crawstone by itself. These changes can be followed by comparing the map and sections (Figs. 9 and 10, pp. 88, 89) with the details of the ironstones on pp. 91, 92.

The yield in tons to the acre or hundredweights to the square yard was calculated in 1836 by Smith[1], and these figures were quoted by Prestwich[2]. W. W. Smyth[3] recalculated their yield in hundredweights per cubic yard. These figures are given below alongside of figures made recently by the principal iron manufacturers:—

	Thickness in feet.	Yield per yard. (Smith).	Yield per yard. (Smyth).	Recent calculations.
		T. C.	Cwts.	Cwts.
Chance Pennystone ...	6	0 4	—	—
Ragged Robins	—	—	—	5
Blackstone...	4	0 8	6	5
Brick-measures	16	0 6	—	—
Ballstone	9	0 5	—	—
Yellowstone	9	0 5	5	5
Blue Flats...	6	0 6	7	6
White Flats	6	0 4	6	6
Pennystone	24	1 4	10	10

From the area of the coalfield large deductions must be made for districts where the ironstones are exhausted or partially exhausted. As early as 1837 Prestwich (*op. cit.*, p. 440) wrote that "almost all the best seams of iron to the west of the Lightmoor Fault and south of Ketley are nearly exhausted." By 1862 W. W. Smyth (*op. cit.*, p. 239) stated that 'a large portion of the coalfield is absolutely exhausted and only a narrow strip of the *exposed* area remains."

Ironstone is, however, still being raised, especially in the northern and eastern parts of the field in the Donnington and Prior's Lee areas, and also near Madeley. Considerable reserves are known to exist, and at the first two localities all the ironstones occur. Together they yield 9,000 tons per acre and underlie an area upwards of five square miles in extent. The total reserves therefore amount to roughly 30 million tons of raw ore. How far the productive measures extend below the Red Measures eastwards is unknown.

[1] 'Miner's Guide,' London, 1836, p. 128.
[2] 'Geology of Coalbrook Dale,' *Trans. Geol. Soc., Ser.* 2, vol. v, 1837, p. 437.
[3] 'Iron Ores of Great Britain,' pt. iv, *Mem. Geol. Survey*, 1862, pp. 240—243.

DETAILS OF THE IRONSTONES.

Crawstone.—This is the lowest measure and consists of large irregular masses of ironstone lying in a fine-grained sandstone. It is of much better quality in the south than in the north, but is practically worked out. Its specific gravity is 3·68.

Pennystone.—This ironstone consists of small, flat, brown nodules lying in dark-grey clay, and increasing in numbers upwards so as sometimes to form a bed. The nodules are cracked irregularly, the cracks being lined sometimes with calcite or barytes, and at others with hydrous silicate of alumina. The stone, where well developed, yields 2,600 tons to the acre. It is less rich in the southern part of the coalfield. At some of the works it was employed alone and produced an excellent pig-iron. In parts of the coalfield the measure consists of the Top or Main and the Bottom Pennystone, and where the latter occurs the yield per acre increases to 3,500 tons. It everywhere rests upon the New Mine or Sulphur Coal. In the south it is crowded with marine shells,[1] and the nodules are frequently covered with worm-castings and burrows infilled with zinc blende.

This ironstone is still worked occasionally near Madeley and Oakengates.

The White Flats.—This ironstone is composed of small, brownish-grey nodules, lying in seams of dark-grey clay, about 20-30 ft. above the Big Flint Coal. It does not extend south of Dawley.

The measure yields about 1,500 tons per acre, but is not so valuable as the other ironstones of the district.

The Blue Flats.—These measures consist of nodular ironstone in hard clay lying below the Yard Coal. The nodules are brownish-grey and full of casts of shells; near the base of the clay they run together into beds. The Blue Flats yield from 1,500 to 1,600 tons to the acre and are used in the manufacture of cold-blast iron. They have not been met with south of Malinslee.

The Yellowstone.—This consists of small, rough nodules, frequently with a conchoidal fracture, or of short thick masses in blackish-grey, dry clay.

It lies immediately above the Yard Coal but does not extend as far south as Dawley. It produces about 1,200 tons to the acre, and is raised occasionally for both hot- and cold-blast iron.

Ballstone.—This ironstone consists generally of two or three layers of large, smooth nodules imbedded in a light-coloured shale. They are remarkable for their richness in fossil plants. This stone was one of the materials used for the production of the best iron. It yields about 1,200 tons per acre.

The Ballstone is underlain by the Dunearth, to which it is similar.

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[1] Prestwich, *op. cit.*, pp. 442—444.

Brick Measure or Brickman Measure.—This ironstone was considered of only secondary importance.[1] It exists in the form of flat cakes with smooth surfaces and of a dark-brown colour, and is divided by cracks into brick-like masses lying in dry clay, about a yard below the Gur Coal. There are sometimes two or three separate layers of this stone. The yield was 6 cwt. per square yard, or 1,450 tons per acre.

The *Blackstone* Measure consists of small nodules with black shiny surfaces embedded in a tough, dark clay. It is not known south of Malinslee. The measures immediately overlie the Stone Coal and yield about 1,500 tons to the acre. It is highly valued for making the 'best best' cold-blast iron.

The Ragged Robins is a black nodular ore, occasionally found in an argillaceous sandstone underlying the Fungous Coal of the Ketley, Hadley and Donnington districts. It is still raised in small quantities and yields about 1,200 tons per acre.

The Top or Chance Pennystone.—This is an irregular deposit closely resembling the main Pennystone which lies about 200 ft. deeper, and like it containing an abundance of marine shells. It lies at about 13 yards above the Fungous Coal.

It does not occur further to the south than New Hadley and Ketley; is still occasionally raised and yields about 1,000 tons per acre.

In the Forest of Wyre Coalfield small quantities of ironstone are occasionally raised, and ironstones were formerly obtained from the Coal Measures of the Clee Hills.

Meade[2] states that "Of other argillaceous ironstones raised in Shropshire, the following analyses, by Mr. Edward Riley, of the 'Light Clod,' and 'Dark Clod' obtained at Billingsley Colliery, at Bridgnorth, will show the general character of the ironstone raised in the Forest of Wyre. The smelting of these ironstones, it has been stated, was formerly an industry in this neighbourhood . . . . and it is said that the iron produced was of very good quality":—

	Light Clod. Per cent.		Dark Clod. Per cent.
Silica	9·99	...	9·87
Carbonate of iron	73.82	...	74.72
Alumina	6·02	...	6·20
Carbonate of manganese	1·13	...	1·16
„ lime	1·16	...	3·25
„ magnesia	2·21	...	2·15
Sulphate of baryta	3·25	...	trace
Phosphoric acid	0·21	...	0·30
Combined water	1·00	...	1·66
Moisture	0·66	...	0·72
Sulphur	—	...	0·03
Sulphate of lime	trace	...	trace
Small quantity of potash and organic matter.			
	99·44	...	100·06
Loss by calcination	36·20	...	28·64
Iron in calcined ore	48·33	...	50·60
Metallic iron	35·66	...	36·01

[1] R. Meade, 'The Coal and Iron Industries of Great Britain,' 1882, p. 481.
[2] *Op. cit.*, pp. 484, 485.

Analyses of Shropshire Iron-ores.

'Iron Ores of Great Britain,' pt. iv, *Mem. Geol. Surv.*, 1862, pp. 243—254.

	(1)	(2)	(3)	(4)	(5)	(6)
Ferrous oxide	48·28	46·30	44·33	45·08	44·19	51·45
Ferric oxide	—	—	1·06	0·55	Nil	Nil
Manganous oxide ...	0·82	0·82	1·00	1·69	0·99	0·54
Alumina	0·67	0·48	0·92	0·43	0·41	0·43
Lime	2·26	2·30	2·86	2·95	1·63	2·13
Magnesia	1·83	2·01	1·97	4·11	3·40	0·42
Carbon dioxide ...	32·98	31·68	30·92	34·04	32·02	33·31
Phosphoric acid ...	0·26	0·50	0·70	0·46	0·29	0·23
Silica, soluble	—	—	—	0·57	0·37	—
Sulphuric acid ...	0·10	0·11	0·06	trace	0·06	—
Iron pyrites	0·19	0·08	0·01	0·48	0·43	0·02
Water at 100° C. ...	0·24	0·28	0·35	0·30	0·45	0·19
Water, combined ...	0·62	0·81	0·95	0·72	1·31	0·54
Organic matter ...	0·62	0·62	0·38	0·23	0·42	0·67
Ignited insoluble residue	11·19	13·24	14·35	8·32	13·50	9·60
	100·06	99·23	99·86	99·93	99·47	99·53
Ignited insoluble residue :—						
Silica	7·36	8·23	9·90	5·66	7·75	6·83
Alumina	3·50	3·78	3·60	1·96	4·64	2·42
Ferric oxide ...	0·53	0·69	0·56	0·26	0·55	0·43
Lime	0·08	trace	0·12	0·16	0·14	traces
Magnesia	trace	0·07	trace	0·09	0·08	traces
Potash	0·10	0·33	0·24	trace	0·33	0·16
Metallic iron	37·92	36·49	35·61	35·63	34·75	40·27

(1) Black Flats (Blackstone), no locality given. (2) Blue Flats, Donnington Wood. (3) White Flats, Donnington Wood. (4) Pennystone, Donnington Wood. (5) Pennystone, Madeley Court. (6) Crawstone, Madeley Wood.

North Wales.

By T. C. Cantrill.

The raising of clay-ironstone from the Coal Measures of the Flintshire and Denbighshire coalfield has been so long extinct that little information is available. A series of iron-ore specimens was shown by Mr. S. H. Blackwell of Dudley at the Great Exhibition of 1851, and from the description published in the official catalogue[1] it appears that at that time the chief ironstones raised in the Ruabon district were :—

1. The Upper Yard Ironstone, consisting of four irregular courses, averaging together about 7 in. in thickness.
2. The Red Coal Ironstone.
3. The Stone Coal Ironstone, in four courses.
4. The Two-Yard Coal Ironstone.

[1] 'Official Descriptive and Illustrated Catalogue of the Great Exhibition . . . 1851,' 8vo, *Lond.*, pt. i, p. 152.

5. The Lower Yard Coal Ironstone.
6. The Wall-and-Bench Ironstones, in six courses, amounting to 12½ in., in about 7 ft. of ground.
7. The Llwyneinion Ironstones, in 15 courses, averaging together 30 in. These were all worked, with the Llwyneinion Coal, in three lifts. Their yield per acre was 8,000 to 9,000 tons.

In addition to the above, the ironstones above and below the Bind Coal and those below the Main Coal were being worked in 1855.

The following generalized section[1] of the Ruabon measures shows the relative positions of these ironstones:—

	Thickness. Ft.	Ins.
Shale and black (? blackband) ironstone	3	6
Bind Coal	1	6
Underclay and ironstone	4	0
Sandstone	4	6
Main or Three-Yard Coal	9	0
Measures (with ironstones)	30	0
Brassy Coal	3	0
Measures with the *Upper Yard Ironstone* at base	24	0
Upper Yard or Crank Coal	2	3
Measures with the *Red Coal Ironstone*	55	0
Red Coal	2	0
Measures with *Stone Coal Ironstone* at base	38	0
Stone or New Coal	2	9
Measures	40	0
Half-Yard Coal	2	10
Measures with Benches, Firedamp and Nant Coals, and *Two-Yard* and *Lower Yard Ironstones*	60	0
Lower Yard Coal	3	6
Measures with *Wall-and-Bench Ironstones* at base... ...	60	0
Wall and Bench Coals	3	0
Measures with *Llwyneinion Ironstone*	55	0
Llwyneinion Coal	1	6

Still lower in the Coal Measures, between the Llwyneinion Coal and the Millstone Grit, the following ironstone-bands occur:—

	Ft.	Ins.
Llwyneinion Coal	1	6
Fireclay and shale	16	6
Shale with five bands of ironstone	4	0
Sandstone and shale	15	0
Shale with six bands of ironstone	18	6
Sandstone with fireclay	20	6
Shale with three bands of ironstone (*Chwareleu Ironstone*)	11	6
Chwareleu Coal	1	6
Underclay and sandstone	13	0
Shale with ironstone	18	6
Sandstone, shale, and grit	28	6
Aqueduct Coal	1	6
Underclay, sandstone and shale	12	6
Shale with six or seven bands of ironstone...	36	0
Millstone Grit (sandstones with shales)	—	

[1] Based on 'Vertical Sections' (*Geol. Surv.*), Sheet 24, and other more recent records collected by Mr. C. B. Wedd.

All these ironstones have probably been worked; the Chwareleu band is mentioned in a list[1] of the Ruabon ironstones being worked in 1855. The bands lying between the Aqueduct Coal and the Millstone Grit may be the rich group mentioned by Meade[2] as having been worked at Trefechan, 2 miles north-west of Ruabon. This ore contained in the raw state 36·31 per cent. of metallic iron, and in the calcined state 51·54, the complete analysis showing:—

	Per cent.
Metallic iron...	36·31
Manganese	1·31
Magnesia	3·39
Lime	3·03
Alumina	0·79
Water	0·96
Carbonic acid	33·06
Phosphoric acid	1·09
Sulphuric acid	trace
Ignited insol. matter	20·06
	100·00

The measures containing the Chwareleu Ironstone and Coal, and the Aqueduct Coal, are well exposed in the Australia clay-pit at Trevor, $2\frac{1}{2}$ miles south-west of Ruabon.

At Mostyn the Coal Measures contain ironstones at the following horizons:—In the shales overlying the Three-Quarter Coal; a band 3 ft. thick below the Three-Quarter Coal underclay; in the shales overlying the Five-Yard Coal; two bands between the last-named coal and the Three-Yard Coal; in the underclay of the Two-Yard Coal; and several bands between the last-named and the Durbog Coal[3].

At Brymbo similar ironstones occur at the following positions:—In the shales overlying the Lower Stinking Coal; over the Two-Yard Coal; above the Brassy[4] Coal; numerous bands between the last-named and the Black Vein Coal; between the last-named and the Main Coal; and also 120 ft. below the Main Coal[5].

The argillaceous ores of Denbighshire (and presumably of Flintshire also) contain from 30 to 36 per cent. of metallic iron.

In 1856 and 1857 the chief collieries and mines raising this kind of ore were Afon Eitha, Brymbo, Bryn Mally, Broughton, Coed Poeth, Dolydd, Ffrwd, Llwyneinion, Plâs-isaf, Quinta, Trefynant, Fron, and Ruabon.

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[1] 'Mineral Statistics,' 1855, p. 49.

[2] 'Coal and Iron Industries,' 1882, pp. 574, 575.

[3] 'Vert. Sect.' (*Geol. Surv.*), Sheet 77.

[4] Not the Brassy of the Ruabon district.

[5] 'Vert. Sect.' (*Geol. Surv.*), Sheet 24.

The output, as given in the Mineral Statistics and, subsequently to 1881, in the Home Office Statistics, is shown in the following columns:—

Output of Coal Measure Ironstones.

DENBIGHSHIRE AND FLINTSHIRE.

Year.	Mine or District.	Tons.	Average value per ton.	Remarks.
1855	North Wales ...	65,820	—	Chiefly Ruabon district.
1856	Denbighshire ...	70,000	—	65,914 from 13 specified collieries, 4,086 from others unspecified.
1857	Denbighshire ...	67,644	—	From 12 specified collieries, plus an unknown amount from Flintshire.
1858	Brymbo ...	31,435	—	Plus an unknown amount from sundry unspecified mines.
	Ruabon ...	17,500	—	
	Flintshire ...	1,050	—	Includes some brown hæmatite.
1859	Brymbo ...	32,622	—	——
	Ffrwd	6,200	—	——
1860	Denbighshire and Flintshire	85,000	—	——
1861	Brymbo and Ffrwd	82,500	5*s.*	——
1862	Denbighshire ...	51,700	—	——
1863	,, ...	27,550	—	Plus some from Flintshire.
1864	,, ...	23,750	—	——
1865	,, ...	97,500	—	——
1866	,, ...	55,690	6*s.*	——
1867	,, ...	43,582	—	——
1868	,, ...	35,813	—	——
1869	,, ...	33,431	—	——
1870	,, ...	59,140	—	——
1871	Brymbo ...	22,875	—	——
	Ruabon ...	8,512	—	——
	Ffrwd	20,500	—	——
1872	Brymbo ...	3,045	—	——
	Ruabon, Ffrwd, etc.	20,000	—	——
1873	Denbighshire and Flintshire	34,426	—	——
1874	,, ,,	41,157	—	——
1875	North Wales ...	40,000	—	More or less.
1876	,, ...	40,952	—	——
1877	,, ...	41,711	—	——
1878	,, ...	42,082	—	——
1879	,, ...	38,936	—	——
1880	,, ...	41,413	—	——
1881	,, ...	24,126	—	——
1882	Denbighshire ...	14,059	7*s.* 6*d.*	——
	Flintshire ...	32	6*s.*	——
1883	Denbighshire ...	4,972	7*s.*	——
	Flintshire ...	nil	—	——
1884	Denbighshire ...	2,819	7*s.*	——
1885	,, ...	2,594	7*s.*	——
1886	,, ...	2,866	7*s.*	——
1887	,, ...	2,713	7*s.*	——

Since 1887 the yearly output has never reached 1,000 tons, and from 1912 to 1916 no ore was raised. In 1910 it sold at 6s. 3d. a ton, and the last output (in 1911) amounted to 341 tons.

Assuming that the principal courses of clay-ironstone in Denbighshire and Flintshire are available over an area of 10 square miles, the reserves have been estimated[1] at 20 million tons.

The smelting[2] of the local ironstones was proceeding as far back as 1740, at which date two furnaces were in operation in Denbighshire. In 1796 there were five: at Brymbo, Brymbo Gate, Pentroba[3], Penyfron and Ruabon. In 1806 the principal ironworks were Ruabon and Brymbo. In 1830 there were 12 furnaces in North Wales, and in 1839 there were 20. In 1854 the furnaces were 11 in number, situated at Brymbo, Coed Talon, Ffrwd, Leeswood, Acrefair near Ruabon, Plâs-isaf, and Plâs-kynaston. Of these, nine were in blast. In 1855-1880 the number varied between 8 and 14. In Denbighshire in 1880 the Brymbo Iron Co. had three, James Sparrow and Son at Ffrwd, Wrexham, had three, and the New British Iron Co. at Ruabon had two; while in Flintshire the Mostyn Coal and Iron Co. had two at Mostyn. In 1916 there were one at Brymbo and three (2 in blast) at Mostyn; but the local clay-ironstones are no longer utilized.

Carnarvonshire.

In 1853 Samuel Haughton[4] recorded pisolitic brown and red hæmatite near a waterfall on the Carnarvonshire shore west of the Menai Bridge, in rocks apparently belonging to the Carboniferous Basement Beds. The ironstone occurs as brown pisolitic concretions in a bed, 1½ ft. thick, of soft purple and blue-green slaty marl, interbedded with red, purple, and white sandstones and conglomerates, and in one place was over 2 ft. thick. The brown ore contains 34·55 per cent. of metallic iron, and the red ore 43·81 per cent.; but the clay and silica amount to 30-37 per cent. The concretions were apparently formed contemporaneously. The deposit is unlikely to be of commercial value.

Cumberland.

By T. C. Cantrill.

The Coal Measures of Cumberland seem never to have supplied more than a trifling quantity of clay-ironstone, presumably by reason of the proximity of the deposits of hæmatite in the Carboniferous Limestone. Meade[5] records nothing more than the presence of a very thin band near the Parkside Mine, Cleator Moor.

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[1] 'Summary of Progress for 1917,' *Mem. Geol. Surv.*, 1918, pp. 7, 22, 23.

[2] Meade, *op. cit.*, pp. 578–581.

[3] *Query* Pentre-Hobin or Pentrobin, near Buckley, in Flintshire.

[4] *Journ. Geol. Soc. Dublin*, vol. vi (1853-4), pp. 1, 13, 14.

[5] 'The Coal and Iron Industries,' 1882, p. 427.

The occurrence of a band of hæmatite derived from the alteration of a thin bed of Spirorbis-limestone in the upper part of the Coal Measures at Millyeat has been referred to in another volume[1].

In former years a small quantity of clay-ironstone was brought up from one or two of the coal-mines in the Workington and Maryport districts and used for foundry-purposes and as a source of malleable iron, but for the last 20 years there has been little or no demand for this kind of ore.

Clay-ironstone in the form of small nodules (called 'catscopes') occurs in the roof-shales of the Metal Band of the Main Coal, the section at the Clifton Colliery[2] at Great Clifton (3 miles east of Workington) being as follows:—

		Thickness. Ft.	Ins.
	Shales with *ironstone-nodules*	1	3
Main Coal	Metal Band Coal, average about	3	1
	Black shales up to	6	0
	Cannel Band Coal, average about	3	1

The nodules are usually about 6 in. in diameter. In working the Metal Band Coal the nodules that came down with the roof-shales were formerly brought to the surface and stored till wanted. The last consignment from Clifton was sent to Messrs. Kirk Bros. of Workington; but that firm having stopped working in 1907 none has been sold since. The analysis of the ore showed about 25 per cent. of metallic iron.

Similar conditions obtain at the pits belonging to the Flimby and Broughton Moor Coal and Firebrick Co.'s mines[3] at Flimby (2 miles south of Maryport).

These ores before use need to be calcined. As this operation forms no part of the treatment to which the local hæmatite is subjected at the Cumberland furnaces, the Cleveland or Midland furnaces are the only ones that could deal with these clayband ores. But the cost of transport would be heavier than this class of ironstone would bear.

According to the Mineral Statistics the output began in 1873 with a total of 1,098 tons from Clifton and Melgramfitz Collieries near Workington, and Ellenborough Colliery near Maryport, the last yielding the largest share; the average value of the ore being 17s. 9d. per ton. Since then the annual output has never risen beyond 1,000 tons except in 1883, 1886 and 1887, when that figure was only slightly exceeded. In 1897 the ore sold at 7s. a ton, and was stated to contain 30 per cent. of iron. Between 1901 and 1906 it sold at 2s. 6d. a ton. Since 1909 there has been no output.

The clay-band ironstones of this district have played such a small part compared with similar ores from other coalfields that no estimate of reserves has been attempted.

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[1] 'Iron Ores: Hæmatites of West Cumberland, Lancashire and the Lake District,' *Mem. Geol. Surv.*, 1919, pp. 13 and 15.

[2] Information from Mr. L. H. Fletcher, of the Allerdale Coal Co., Ltd., Workington.

[3] Information from Mr. Lloyd Wilson.

Gloucestershire and Somerset.

By T. C. Cantrill.

Clay-ironstones were formerly worked in the Bristol district. Ashton Vale, on the south-west side of Bristol, was the chief locality where these ores were raised and smelted. Here the ironstones were obtained from the lowest or Vobster Group of the Lower Coal Series, their positions being shown in the following approximate section[1] of the Ashton Vale New Pit:—

	Thickness. Ft.	Ins.
Parker's Top Coal, 3 ft. to 6 ft., say	4	6
Underclay	2	0
Shales with balls of *ironstone*	39	6
Parker's Middle Coal	2	9
Underclay	11	0
Shales with balls of *ironstone*	27	6
Parker's Lower Coal	3	3
Underclay with a 12 in. coal	6	6
Shales, with a 12 in. coal and its underclay ...	59	0
Shales with balls of *ironstone*, about	3	0
Underclay and shales	58	0
Balls of ironstone, several inches, say	0	2
Shales	65	0
Shales with balls of *ironstone*	12	0
Ashton Top Coal...	4	0
Fireclay and shales	39	6
Ashton Great Coal	4	6
Underclay, shales and fireclay	121	6
Ashton Little Coal	2	0
Shale	8	0
Millstone Grit	—	—

Similar ores were worked at the Kingswood Collieries, where, at the Hopewell Pit, operating at one time exclusively for ironstone, a seam of blackband, immediately overlying the Giller's Inn Coal, was also raised. This coal lies 440 ft. above Parker's Top Coal, and the section[2] of this part of the measures is as follows:—

	Ft.	Ins.
Fireclay and *ironstone*	4	0
Great Coal	4	6
Underclay, shale and sandstone	15	0
Shale, with four bands of *ironstone*, the upper one 9 ins. thick; another is called the 'worm-bed'	26	0
Bass and balls of *blackband ironstone*	3	0
Giller's Inn Coal	1	10
Shale, fireclay and blacks	59	0
Coal	0	11
Shale with 6 ins. of ironstone	7	0
Little Toad Coal	1	6

Still higher in the sequence a 9-in. band of ironstone occurs between the Hole or Hard Coal and the Five Coals, and another of like thickness close above the Hole Coal; others are present below the Red-Ash Coal, between the Lyalong Coal and the Old Toad Coal, and at several higher levels.

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[1] 'Vertical Sections' (*Geol. Surv.*), Sheet 51.

[2] *Ibid.*

In the western end of the Nettlebridge Valley, 4 miles south of Radstock, clayband ores were raised near the Old Moorwood Colliery. They occur in the shales associated with the Dungy Coal and at numerous higher horizons.[1]

The outputs of these ores (in tons), so far as they can be ascertained from the Mineral Statistics, are as follows:—

Output of Coal Measure Ironstones.

Bristol and Somerset.

Year.	Bristol District (Sundry mines)	Ashton Vale.	Remarks.
1856	500	—	—
1857	7,500	—	—
1858	1,200	2,616	—
1859	1,570	2,000	—
1860	1,500	3,960	Value 10s. per ton.
1861	1,500	7,300	The Ashton Vale figures include the Ashton Hill hæmatite.
1862	1,750	342	Ditto. Value 5s. per ton.
1863	?	?	Bristol, Ashton Vale and Ashton Hill hæmatite merged.
1864	3,500	12,965	The Ashton Vale figures include the Ashton Hill hæmatite.
1865	3,475	6,348	Value 10s. per ton.
1866	2,500	2,720	,, ,, ,,
1867	2,000	2,350	—
1868	1,765	2,760	—
1869	1,500	1,646	—
1870	975	2,051	Value 7s. per ton.
1871	1,000	1,673	,, 20s. ,,
1872	1,000	?	Ashton Vale merged in Bristol.
1873	1,012	620	—
1874	500	952	Value 15s. per ton.
1875	550	1,015	,, 10s. ,,

From 1875 onward the localities are not specified, the returns for the county (Somerset) alone being published. The figures are as follows:—

Year.	Tons.	Year.	Tons.
1876 ...	2,074	1881 ...	488
1877 ...	1,522	1882 ...	131
1878 ...	3 ?	1883 ...	26
1879 ...	nil	1884–1916 ...	nil
1880 ...	644		

In 1881 the value of the ore was 10s. a ton; in 1882 it was 7s., and in 1883 it was 6s. The ores were smelted partly in South Wales, partly at local furnaces. About 1857 a furnace was set up at Pennywell Road, Bristol, but was abandoned about 1865. In 1859 the Ashton Vale furnaces were projected, and in 1860 produced 1,960 tons of pig-iron. They were blown out about 1876. While in operation they smelted not only the clay-ironstones from the Ashton Vale collieries, but also hæmatite from Somerset, as well as ores from distant parts of England.

No estimate of reserves of these ironstones has been attempted, as they have contributed only a small part of the output of clay-ironstones when compared with those of other coalfields.

[1] 'Vert. Sect.' (*Geol. Surv.*), Sheet 52.

CHAPTER VIII.

CARBONIFEROUS BEDDED ORES—(*contd.*).

South Wales and Monmouthshire.

By Sir A. Strahan.

INTRODUCTION.

The working of the clay-ironstone or 'mine' of the Coal Measures of South Wales is an old industry. In 1740 it became nearly extinct through the scarcity of wood for smelting, but it revived in 1755 when Anthony Bacon used pit-coal for that purpose at Merthyr, which seems to have been the birth-place of the industry. Before the end of the century communications were established with the sea-ports by canals and tramroads.[1]

The output in 1856 amounted, according to the Mineral Statistics, to upwards of $1\frac{3}{4}$ million tons, but it was remarked in 1858 that the local ores had not been sufficiently developed to meet the requirements of the trade, and that large quantities of ore were being imported from the northern and south-western parts of England, and from abroad. In 1860 the output had dwindled to about $\frac{1}{2}$ million tons a year, and since has decreased to less than 20,000 tons a year. In 1895, when the six-inch geological survey was in progress, mine was being raised in two or three localities only, in Monmouthshire and East Glamorgan, and the greater part of the output was attributable to the fact that when it was necessary to drive through mine-ground to win coal it was worth while to reserve for sale such mine as was raised. A little is still used locally (at Ebbw Vale), but the bulk appears to be sent to South Staffordshire furnaces.

The following table illustrates the decline of the industry for the years covered by the Mineral Statistics (1855-1881) and Home Office Statistics (1882 and after). The figures for 1857 and 1858 have been filled in from 'The Coal and Iron Industries of the United Kingdom,' by R. Meade, 1882, p. 599.

Output of Coal Measure Ironstone in South Wales and Monmouthshire.

	Tons.
1855	1,665,500
1856	1,784,700
1857	1,013,941
1858	727,596
1859	607,558
1860–69, yearly average...	445,445
1870–79, ,, ,, ...	519,225
1880–89, ,, ,, ...	100,576
1890–99, ,, ,, ...	31,599
1900–09, ,, ,, ...	19,734
1910–17, ,, ,, ...	17,084

[1] For the history of iron-mining in South Wales reference should be made to 'The History of Merthyr Tydvil, by Charles Wilkins, Merthyr-Tydfil, 1867, and to 'Observations on the Clayband-ironstone or "Mine" of the Northern Outcrop of the South Wales Coal Field,' by Thomas Joseph. *Trans. S. Wales Inst. Eng.*, vol. xii, 1880–81, p. 255.

The bulk of the ore was got in Monmouthshire and Glamorgan. The annual outputs from Breconshire and Carmarthenshire fell below 1,000 tons in 1885, and in the whole period the total output from Pembrokeshire amounted to only 183 tons, raised in the years 1896 and 1897.

The ore was got partly by levels, partly by open excavations or 'patch-works,' which on the broad outcrops of gently inclined strata attained an enormous size. It occurs in bands or 'pins' and as nodules or 'balls,' imbedded in shale, and after extraction was left out in the weather, to be freed from adherent shale by frost and rain, a treatment to which outcrop-ore yielded more readily than that which had been mined. The cost of mining was increased also by the greater hardness of the shale under cover. The removal of the shale was effected where possible by 'scouring'; that is by allowing a rush of dammed-up surface-water to pass over the previously loosened material. 'Scouring' appears to have caused much damage by spreading shale over valuable land, and to have led to lawsuits.[1] Only such coal was raised in the ironstone-workings as was required for local purposes.

The distribution and composition of the ores were made the subjects of examination by the Geological Survey in 1861. Their distribution was described by Mr. E. Rogers and the making of analyses was rendered possible through the liberality of Mr. Samuel Rogers, of Dudley. The results of the investigation appeared in 'Iron Ores of Great Britain' (*Mem. Geol. Survey*), part iii, 1861, and from this work the analyses tabulated after p. 114 have been taken. Of later years accounts of the local distribution have appeared in the Explanatory Memoirs, one of which accompanies each sheet of the New Series one-inch Geological Map. Among other sources of information reference should be made to the exhaustive paper by Mr. Joseph already referred to, and to 'The Coal and Iron Industries of the United Kingdom' by R. Meade, published in 1882.

LOCAL DETAILS.

In the following account the districts in which the iron-ores were worked are taken in geographical order from east to west. They extend from Pontypool in Monmouthshire along the North Crop to the Gwendraeth Valley in Carmarthenshire, and to Cwmavan near the South Crop in Glamorgan.

Llanfabon, Risca and Pontypool.

The highest workable bed of ore occurs in the Upper Coal Series between the Rhymney and Taff Valleys. It consists of a blackband lying "about 27 yards above the Mynyddislwyn Vein. At Wingfield, $1\frac{3}{4}$ miles north of Gelligaer, it consists of good ironstone 2 ft. thick, a shale-parting $2\frac{1}{2}$ ft. thick, and a lower ironstone 2 ft. 3 in. thick; near Gilfach it includes five bands of ironstone, totalling 4 ft. 11 in. in thickness, with partings amounting to 3 ft. $8\frac{1}{2}$ in."[2] At Llancaiach Colliery the same band is recognised, but is rather thinner.

[1] T. Joseph, *op. cit.*, p. 267.

[2] 'The Country around Newport,' *Mem. Geol. Surv.*, 2nd ed., 1909, p. 80.

A blackband, or carbonaceous clay-ironstone, lying above the No. 2 or Charcoal Seam of Abercarn and Rock Vein of Risca, was formerly worked. This presumably is the ironstone of which an analysis is given after p. 114. It is on approximately the same horizon as the Old Man's Coal of Ebbw Vale, with which also a blackband was associated.

In the Lower Coal Series there are many courses of mine-ground, most of which have been worked in one part or another. The 'patches' upon the Elled Mine-ground and Coal are among the most extensive. The Three-Quarter Balls were remarkable throughout the eastern part of the coalfield for the fact that they abounded in fissures and cracks which contained needle-shaped crystals of sulphide of nickel (millerite), a hydrocarbon or mineral tallow (hatchettine[1]), quartz-crystals, calspar and spathose iron-ore. The cavities were often filled with water of a saline taste.

The lowest course of iron-ore occurs locally in the Millstone Grit north of Beaufort, and was worked under the name of the Rosser Veins; these must not be confounded with the Rosser Veins which occur in the lowest Coal Measures.

The following abstract of a part of the shaft-section of the Glyn Colliery[2] near Pontypool shows the relative position of the principal coals and ironstones in that part of Monmouthshire:—

	Thickness.		Depth from surface.	
	Ft.	In.	Ft.	In.
Soap Vein Mine Ground with three small pins ...	16	6	101	0
Measures	52	6	—	
Soap Vein Coal	2	6	—	
Measures	30	4	—	
Black Pin Mine Ground, with two irregular pins and irregular balls, making together 10 ins.	15	0	201	4
Measures	60	6	—	
Elled Coal	4	0	—	
Measures	43	6	—	
Droideg or Big Vein Coal	4	0	—	
Measures	31	6	—	
Blackband Mine	3	9	348	7
Red Vein (Three-Quarter) Coal	3	8	—	
Measures	16	0	—	
Shale containing, in the lower part, the *Rock Vein Balls*, two seams about 6 ins. each	54	0	422	3
Rock Vein Coal	8	0	—	
Measures with Yard Vein Coal	39	6	—	
Meadow Vein Shale, with two courses of mine of 5 and 4 in.	9	0	478	9
Measures	25	0	—	
Meadow Vein Coal, with partings	10	2	—	
Measures	15	6	—	
Old Coal	5	6	—	
Measures	22	8	—	
Spotted Mine Ground, with 10 in. of mine	6	6	564	1
Measures	4	1	—	
Rough Coal	1	10	—	

[1] Conybeare, Rev. J. J., *Ann. Phil.*, ser. 2, vol. i, 1821, p. 136, and Johnston, J. F. W., *Phil. Mag.*, ser. 3, vol. xii, 1838, p. 338.

[2] The complete section is shown in Vert. Sects., *Geol. Surv.*, Sheet 80, No. 9.

Cwm Celyn and Blaina (Ebbw Fâch Valley).[1]

The principal ironstones worked at the Cwm Celyn and Blaina Ironworks in 1860 were the Soap Vein, the Black Pins, the Spotted Vein, and the Red Vein. Their positions relatively to the principal coal-seams are shown in the section given on pp. 105, 106.

The following measurements were taken in the workings in the year mentioned:—

Soap Vein.[2]

		Ft.	In.
Top Mine	*Vein*	0	2
	Ground	1	10
	Two-inch Pin	0	2
	Ground	2	1
	Tobacco Pin (contains millerite)	0	1
	Ground	0	2
	Snuff Pin	0	0½
	Ground	2	0
Bottom Mine	*Rashin* (contains hatchettine in cavities)	0	3
	Rashin mine-ground	2	0
	Pin	0	1½
	Soap Vein Coal	1	0

Metallic sulphides are rare in these ironstones as compared with those of central England. Quartz on the other hand is more frequent.

The Tobacco Pin though thin is an excellent stone. The Two-inch Pin and the Vein above it are somewhat poor.

Black Pins.

	Ft.	In.
Black Pins	0	4
Ground	1	2
Yellow Pin	0	4
Ground	3	4
Pin-ammal	0	3
Ground	1	3
Pin-gôch (red)	0	2½
Ground	2	11
Holkin	0	3
Ground	1	1
Double Pins	0	2
Ground	0	6
Pilsen (*pills*)	0	3
Ground	1	8
Grey Vein	0	2
Ground	0	10
Tobacco Pins	0	2
Ground	0	6
Black Pin	0	1
Ground	1	0
Grey Pin (*Pin-glâs-bach*)	0	3

[1] This account is condensed from the description given in 'Iron Ores of Great Britain,' *Mem. Geol. Surv.*, pt. iii, 1861, pp. 193–5.

[2] The Soap Vein here described lies immediately above the Soap Vein Coal and is not the Soap Vein Mine Ground of the Glyn Pit section given on p. 103. Both mine-grounds were recognised in the Varteg Hill Colliery, Nant Ffrwd. (*Vert. Sects. of the Geol. Surv.*, Sheet 81, No. 7).

This last is accompanied by 'jack,'[1] sometimes both above and below, and exhibits numerous vertical cracks or joints with crystalline quartz and, not infrequently, hatchettine.

Spotted Vein.

	Ft.	In.
Pins	0	7
Ground	2	3
Pin	2	0
Ground with balls	1	10

Red Vein Measures.

	Ft.	In.
Upper Pin	0	1½
Red Vein	3 to 4	
Pins or Cakes	2 to 4	
Black Mine	3 to 4	

These ironstones lie in about 6 ft. of ground.

The Red Vein is accompanied by some 6 in. of 'jack,' or argillaceous stone, containing a small percentage of iron, and exhibiting cone-in-cone structure.

The Red Vein and the Black Mine contain hatchettine in cracks and hollows.

Ebbw Vale.

The following details of the ironstones are extracted from a general section of the strata of Ebbw Vale made by Mr. W. Adams and published in 'Iron Ores of Great Britain,' part iii, 1861, pp. 172-9.

	In.		Ft.	In.
Soap Vein Mine, about 3 in. thick, in shale			5	0
Strata [with Soap Vein Coal]			43	0
Upper Black Pin	3	⎫		
Pin Harry Walter Lewis ...	0½	⎪		
Pin-ammal	1½	⎪		
Red Pin	1½	⎪		
Upper Bachwen	1½	⎪		
Lower ,, ...	1	⎪		
Upper Holkin	2	⎬ Black Pins Mine-ground	30	0
Lower ,, ...	1	⎪		
Pilson	1½	⎪		
Brown Vein	2½	⎪		
Chance Pin	0½	⎪		
Black Pin	1½	⎭		
Bottom Vein	4			
Strata			54	10
Ell Balls in shale			4	0
Ell Coal			3	10
Strata			9	3
Big Vein Coal			5	3
Strata			7	1
Three-Quarter Balls in mine-ground			3	1½
Strata			4	5
Three-quarter Coal			3	2
Strata			133	2
Gough's Mine in mine-ground			5	11
Strata			12	0

[1] A yellow calcareous stone containing a little iron.

	Ft.	In.
Bydylog Coal	3	3½
Strata	21	7
Upper Darren [*Daren*] *Mine*	0	3½
Strata, with Engine, Little Red and Yard Coals	131	0
Old Coal	6	8
Strata	13	11
Spotted Vein Mine	0	8
Strata	38	6
Red Vein: *Top Vein Mine*	0	4
Strata, mine-ground	5	4½
Spotted Pin (*Pin Bryth* [*Brith*])	0	2½
Strata, mine-ground	7	0
Blue Vein Mine (*irregular*)	0	3
Strata, mine-ground	14	7
Big Vein Mine, Top Vein	0	2
Shale	1	9
Holing Pin	0	1½
Shale	3	0
Bottom Course	0	2
Shale	2	3
Nappwg [*Cnapiog*] *Pin*	0	1½
Shale	3	0
Pin Garrw [*Garw*]	0	1½
Shale	2	0
Bottom Vein Coal	2	0
Fireclay	1	0
Farewell Rock		

The yield per acre of the ironstones of 'Coalbrook Vale' (in Ebbw Vale) are given by Meade as follows:—[1]

	Number of courses.	Aggregate thickness. In.	Tons per acre.
Soap Vein Mine	4	7	2,000
Black Pins	10	—	4,500
Three Quarter Balls	3	—	1,200
Spotted Pins	2	4½	1,200
Little Pins (Nant-y-glo)	2	5	1,400
Red Vein (Nant-y-glo)	3	6½	1,800
Big Vein, worked with the Bottom Coal	2	6	1,700

RHYMNEY.

The following section of the Rosser Veins of the lowest Coal Measures is summarised from 'Iron Ores of Great Britain,' part iii, 1861, p. 168:—

Abstract of a section made at Rhymney by Mr. R. Bedlington.

	Ft.	In.
Coal, Rough Pin ['Pin garrw' of the preceding section]	1	8
Shale with four pins	17	6
Upper Rosser Vein	0	2–2½
Shale	2	10
Lower Rosser Vein (average)	0	12 [2]
Shale	2	6
Farewell Rock	—	

[1] 'The Coal and Iron Industries of the United Kingdom.' 1882, p. 585.

[2] Thickness as in the original. A misprint may be suspected.

The next highest ironstone of the Coal Measures is the Pin Garw, overlying the Garw (Rough) Coal of the above section. It is titaniferous. In the eastern part of the area these are represented by the Big or Bottom Vein Coal and the Big Vein Ironstone. The latter includes 6 in. of ironstone in two courses, and yields 1,700 tons per acre according to Meade.[1]

The Old Coal is associated with a blackband ironstone, of good quality but limited extent, which was in great request near Beaufort and Nant-y-glo.

Taff and Cynon Valleys.

The following sections show the principal ironstones of the Taff and Cynon Valleys. The Rosser Vein was formerly worked on both sides of the Taff Valley:—

Abstract of a section at Plymouth Iron Works, Taff Valley.
Communicated by Mr. W. Green.

	Ft.	In.
Ras Las Coal	8	0
Strata	3	10
Brass Vein Coal	4	0
Strata	6	3
Lloyd's Little Vein, with three *ironstones*, 2, 2, and 2¼ ins.	3	8½
Strata with coals	167	0
Bottom Gellideg Coal	2	2
Strata	12	2
Little Vein Ironstone	0	3½
Upper Pins Mine shale, with two *ironstones* 3½ and 1 in.	8	0½
Strata	21	7
Blue Veins Mine shale with three *ironstones* 4, ½, 2½ ins.	5	7
Strata	10	8
Jack Veins Main shale, with five *ironstones*, 3, 3, 1, ½ and 2½ ins.	9	5
Strata	10	1
Tobacco Pin	0	1½
Mine-shale	3	0
Double Knobbed (Cnapiog) Pin	0	2½
Mine-shale	0	11
Pins Mine shale with three *ironstones*, 2, 2, and 3 ins.	8	4
Garw or Cnapiog Coal	1	3

Abstract of a Section of the New Pit, Aberdare Iron Works, 1841, *Cynon Valley.*
(Communicated by Mr. W. Green.)

	Ft.	In.
Ras Las Coal	9	0
Strata with Dirty Coal	116	1
Yard Coal	3	1
Rock	9	0
Mine-ground	13	0
Black Vein Ironstone	0	4
Mine-ground, with three *ironstones*, 7 (inferior), 4, and 1½ ins.	21	9½
Blue Pins, with *ironstone*, 2 ins.	5	2
Strata	28	8
Blue Veins, with two *ironstones*, 5 and 2½ ins.	3	0½
Mine-ground	16	0
Rock	9	0
Mine-ground, with three *ironstones*, 6, 3 and 3 ins.	18	9
Coal [Garw Seam]	1	6
Mine-ground	16	6
Rosser Veins, with two *ironstones*, 6 and 4 ins.	4	0

[1] 'The Coal and Iron Industries of the United Kingdom,' 1882.

Much ironstone was formerly raised from Nant Gwerelech, by level and patch-work. Recourse was had here to 'scouring,' that is to washing the ironstone out of its matrix by floods of water. The gashes thus caused and the detritus from them are still conspicuous. The following section has been condensed from a section supplied by Mr. T. Criswick. The Blewers Coal lies about 180 ft. below the Big or Nine-feet Seam:—

Aber Gwerelech.

	Ft.	In.
Rock top		—
The Eleven Pins Mine-ground	10	5
Measures	70	5
The Five Pins Mine-ground	3	9
Measures	61	0
The Blewers Vein Mine-ground	13	0
Shale	3	7
The Blewers Coal	3	0
Measures	25	11
The Brown Vein Mine-ground	2	8½
Measures	14	7
The Rhied [Rhyd] Vein Mine-ground	2	9½
Measures	25	0
The Yellow Pin Mine-ground	4	2
The Spotted Vein Mine-ground	6	4
Measures	18	4
The Blue Vein Mine-ground	6	9½
Measures	14	8½
The Little Blue Vein Mine-ground	7	8¾
Measures	13	10
The Knobby (Cnapiog) Vein Mine-ground	8	11½
Shale and mine	7	0
The Garw Mine	0	3½
Mine-ground	1	10
Garw Coal	1	8
Measures	8	7
The Upper Rosser Vein Mine-ground	5	11
Shale with mine	20	9½
The Middle Vein Rosser Mine-ground	9	2½
Shale with mine	15	10

At Onllwyn the Grey Vein Coal lies 19 ft. 6 in. below the Rhyd (or Rhied) Coal, and below the Grey Vein Coal lie measures containing the Yellow and Black Pins, Ribbing, Llyfrau and Little Blue Veins of ironstone.

Tawe Valley.

In this valley and westwards from it ironstones at a higher level in the Coal Measures than those of Dowlais and Aberdare were worked in the northern part of the coalfield. The highest of these was the Penny Pieces which lies about 40 ft. above the Stwrain (Two-feet Mine) Coal and about 320 ft. above the Big Nine-feet or Ras Las Coal. The following section was measured by Mr. F. H. Bell in an old level near Penrhos, in the Tawe Valley where it traverses the North Crop:—

Penny Pieces Mine-ground.

	Ft.	In.
Rock-roof	3	0
Rock-pin	0	3
Shale	2	6

	Ft.	In.
White Pin	0	2
Double Pin	0	4
Shale with *balls*	8	0
Mine	0	3
Shale	11	0
Coal	1	0

The following section shows the continuation of the sequence[1]:—

	Ft.	In.
Penny Pieces Mine	—	
Strata	39	0
Stwrain Coal	—	
Strata with *Black Pins* and *Gwythien-fraith Mines* ...	39	6
White Coal	—	
Strata with Pengraig (Four-feet or Cornish) and Harnlo Coals	213	0
Big or Nine-feet Coal	—	
Strata with Brass Vein Coal	124	0
Four courses of *ironstone* and a coal 2 ft. thick	—	
Strata	60	0
Enoch Blewers Mine and Blewers Coal, 3 ft.	—	
Strata	28	0
Ironstone	—	
Strata	6	0
Rhyd Coal	—	
Strata with Grey Coal	111	0
Black Mine—		
Strata	34	0
Gwythien-fach or *Llyfra Mine*—		
Strata	25	0
Las-fach Mine—		
Strata	24	0
Cnapiog or *Knobby Mine* (equivalent to the *Garw Mine* of Dowlais).		

In this neighbourhood the Big Vein Coal and the Brass Vein Coal each contain a band of pyrites, or of granular coal traversed by threads of pyrites. Large quantities of pyrites exist in the waste-heaps along the old coal-workings.

Amman and Gwendraeth Valleys.

The following section of the mine-ground at the Amman Iron Co.'s Collieries, Brynamman, is summarised from a section given by Mr. Thomas Joseph, *op. cit.*, Plate 63:—

	Ft.	In.
Shale with *three pins*, 2½, 3 and 3 ins.[2]	14	8½
White Coal	2	0
Shale with *two pins*, 6 ins. each[2]	13	6
Black Coal	—	
Shale	15	0
Black band	1	6
Strata	44	0
Shale with *six courses of mine*, 4, 1½, 5, 3, 3, and 1½ ins.[2] ...	15	11
Upper Pencraig (Lillie Vein) Coal	3	10
Strata	27	0

[1] Further details are given in Vert. Sects. of the Geol. Survey, Sheet 85, Sects. 13–19.

[2] Worked in 1880 by the Amman Iron Co.

	Ft.	In.
Mine Pin	0	4
Shale	2	0
Lower Pencraig (Harnlo) Coal	2	0
Strata	56	0
Shale with *four pins*, 3½, 1½, 3½ and 3 ins.[1]...	18	11½
Big Coal	5	6
Strata with Black Vein Coal...	81	9
Shale with *three pins*, 2½, 2 and 1 ins.	10	0½
Brass Vein Coal	4	0
Strata	15	0
Shale with *seven courses of mine*	21	8
Shale	15	0
Shale with *four pins*, 2½, 2½, 3 and 1½ ins.[1]...	7	9½
Trigloin coal	—	

Clean 'Big Vein Mine,' well weathered, is stated to have yielded frequently 34·5 per cent. of iron; 'Black Vein Mine,' 33 per cent.; 'Pencraig' or 'Little Vein,' 31 to 32 per cent., and Tregloin Mine, 27 to 28 per cent.

The workings "at Brynamman lie along the south side of the Amman Valley for about a mile and three-quarters, and the ore was smelted at adjacent furnaces; a large pile of slag may be seen south of the Great Western Railway Station. There are numerous patches in Cwm Garnant and they extend westwards across Nant-y-gath; there are others north of Gelli-caedrum."

"At Gors-lâs, 3 miles west-south-west of Llandybie, the ironstone associated with the Lower Pumpquart and Lower Triquart Coals was opened up about the year 1804, and a tramline constructed thence to the blast-furnaces at Llanelly, but the enterprise seems soon to have been abandoned."

"At Pontyberem blast-furnaces were in operation some years ago, the ore chiefly smelted being the Rhâs-fâch Mine from the neighbourhood of Pont Henry."

"A blackband, 1 ft. 8 in thick, was much worked under Farteg Hill and Rhôs Common; it lies between the Red and Four-feet Veins."[2] Others have been tried.

Cwmavan and Maestêg

The Cwmavan series is fully illustrated by a section drawn up by Mr. David Thomas.[3] A Yard Seam is the lowest coal, but below it there are ironstones which have been worked by slips and shafts, and which may correspond with the ironstones below the Cribbwr-fawr Seam on the South Crop. The principal workable beds according to Mr. Thomas are the Sulphury, Cefn-y-glo, Middle Clay, Coal-and-Mine, Five-feet, Jack and Black Mine. Ironstone, in nodules or bands, occurs in close proximity to every seam of coal in this division of the measures. The Sulphury Mine, of which an analysis is given in the table following p. 114, is described as occurring between the Finery and Sulphury seams of coal, and as enjoying a high repute.[4]

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[1] Worked in 1880 by the Amman Iron Co.

[2] 'The Country around Ammanford,' *Mem. Geol. Surv.*, 1907, pp. 216, 217.

[3] *Proc. S. Wales Inst. Eng.*, vol. vii, 1872, p. 317.

[4] 'Iron Ores of Britain,' *Mem. Geol. Surv.*, part iii, 1861, p. 210.

In the neighbourhood of Maestêg a Blackband Ironstone was in great request, and appears to have been worked almost continuously. Farther west, except around Cwmavan, less has been got, perhaps in consequence of deterioration.

This band is associated with the Blackband Coal, which lies 111 ft. below the Clay Coal and 82 ft. above the Victoria Coal in the Dyffryn Rhondda Colliery.[1] The Victoria Coal lies approximately 570 ft. above the Truro Coal, mentioned in the section on p. 112. The Blackband Ironstone varies in thickness from 2 ft. 10 in. on the eastern side of the Avan Valley to 9 in. on the western side, and yielded the following analyses according to Mr. T. Forster Brown:—[2]

Analyses of the Blackband Ironstone near Maestêg.

	Top of Lower Black Band Half-seam.	Bottom of Lower Black Band Half-seam.	Top of Upper Black Band 5th Seam.	Bottom of Upper Black Band 4/5th Seam.
Carbonate of iron ...	74·740	76·030	40·60	64·96
,, manganese	3·120	2·916	3·36	3·60
,, lime ...	4·000	2·900	2·94	3·13
,, magnesia ...	3·780	4·740	1·50	2·15
Phosphoric acid ...	0·828	0·960	0·44	0·76
Insoluble residue } Silicate of alumina }	6·800	5·000	35·20	18·00
Coaly matter	6·240	6·800	15·00	7·20
	99·508	99·346	99·04	99·80
Iron per cent. in the raw ore	36·08	36·8	19·6	31·36
Iron per cent. in the roasted ore	55·4	57·4	26·8	42·7

The lower ironstones, formerly worked in the Maestêg Ironworks, are mentioned in a section by Mr. David Smith, published in part in the Geological Survey Memoirs, vol. i., 1846, p. 189. The following is a summary of that part of the section in which the coals and ironstones are recognised by name in the original MS.:—

	Ft.	In.
Yellow Pin Ironstone	0	6
Shale	9	0
Course of ironstone-balls, named the *Ballsag*	0	5
Shale containing six courses of black ironstone-balls or black pins	12	0
Black Pin Balls	0	6
Shale	3	9
Upper Six-feet Coal	6	0
Fireclay	2	4
Coal	2	0
Measures	32	0
Double Pin	0	6
Shale	6	0

[1] 'The Country around Pontypridd and Maestêg,' *Mem. Geol. Surv.*, 2nd ed., 1917, p. 140.

[2] *Proc. S. Wales Inst. Eng.*, vol. ix, 1875, p. 72.

	Ft.	In.
Truro Coal	3	0
Black shale	6	0
Lower Six-feet Coal	6	0
Measures	36	0
Ironstone-balls...	0	4
Measures	14	0
Pin Haulkin	0	4
Shale with ironstone-balls	42	6
Furnace or Nine-feet Seam	12	0

The South Crop.

For the following section of the mine-ground overlying the Bodwr-fach Vein at Brynau-gwynion near Llanharan, we are indebted to Mr. I. T. Rees:—

	Ft.	In.
Rock	—	—
Pin of mine	0	4
Shale	1	6
Pin	0	4
Blue shale	1	8
Pin	0	6
Shale	5	0
Pin	0	4
Shale	0	6
Blackband	0	9
Clay	0	2
Blackband	0	9
Clod	0	6
Coal [Bodwr-fach Vein ?]	—	—

The veins of ironstone formerly worked south-west of Cefn Colliery range from 9 to 15 in. in thickness. The Garw Pin was the chief bed worked. No ore is now raised from the South Crop, and the blast-furnaces at the Tondu Ironworks were blown out about the year 1889. The following abstract of part of a section communicated by Messrs. Lawrence and Hann, gives the positions of the principal ironstones:—

Measurements made in North and South Drifts, Bryndu.

	Ft.	In.
Cribbwr-fawr Coal	6	0
Measures and mine-ground	27	11
Black Pin Ironstone	0	4
Black Pin Mine-ground with *balls*	12	0
Rock	3	0
Yellow Vein Mine-ground with *ironstone*, 6 to 9 ins. ...	4	6
Rock	6	0
Strong *Mine-ground*	11	0
Red Mine-ground with six courses of *ironstone*	15	0
Mine-ground with *balls*	9	0
Double Pin Ground: *Ironstone*	0	2
Double Pin Ground: Mine-ground	3	9
Double Pin Ground: *Ironstone*	0	5
Double Pin Ground: Mine-ground	3	0
Double Pin Ground: *Ironstone*	0	6
Measures	28	0

		Ft.	In.
Blue Vein Ground	*Ironstone*	0	1½
	Mine-ground	2	0
	Ironstone	0	4
	Clift	2	0
	Ironstone	4	0
	Clift	5	0
	Ironstone	0	3
Clift, mine and clod		18	3½
Pin-garw Ironstone		0	6
Ground		5	0
Little Pin-garw Ironstone		0	3
Mine-ground		4	0
Cribbwr-fach Coal		2	10

PEMBROKESHIRE.

The mine-ground which has been worked in Pembrokeshire, under the name of the Kilvelgy Mine-measures, is associated with small seams of anthracite near the base of the Coal Measures, at a lower geological level than the principal ironstones of the main coal-field. The ore was got by patching and tunnelling into the cliff between Amroth and Saundersfoot, and was smelted at Stepaside. The working of mine was confined to the eastern part of the county.

The Kilgetty slate-mine, which lies next above the Scad Vein of coal, was got in Burrows Patch, and the Catshole Mine which rests upon the Catshole Vein of coal, was got by levels in the Craigdam in the brow of the same cliff. Bridge Patch and Lloyd's Patch, in the same cliff farther south, were both opened in the Fiddler's Pins, at a considerably higher horizon. Mine was also raised in the cliff under Hean Castle from measures above the Lower Level Vein.

"Analyses of some of the ores are recorded in the books of the Pembrokeshire Coal and Iron Company. The Catshole Pins from the No. 1 Level, Craigdam, analysed by Prof. Miller in 1858, yielded the following result:—

Protoxide of iron	27·62	Metallic iron 21·66
Peroxide of iron	0·33	
Protoxide of manganese	0·09	
Magnesia	10·17	
Carbonic acid	19·22	
Silica	31·80	
Alumina	8·00	
Water combined	1·19	
Sulphur, lime and phosphoric acid	traces	
	99·22 [98·42]	

Assays made by Mr. E. Handfield Morton in 1873 showed that:

	Per cent. Metallic iron.
Catshole Pins from Staggers Hill	yielded from 12·33 to 31.86
Fiddler's Pins from Bridge Patch	„ „ 25·70 to 32·63
Slate on Kilgetty Vein, Burrows Patch	„ „ 16·44 to 39·32
Catshole Pins from Cwms	„ „ 24·41 to 30·06
Constant Leader Balls, Bonville's Court	„ „ 27·75 to 28·78[1]

Other analyses of Pembrokeshire clay-ironstones are given in the table following p. 114.

[1] 'The Country around Haverfordwest,' *Mem. Geol Surv.*, 1914. pp. 162, 163.

RESERVES IN SOUTH WALES AND MONMOUTHSHIRE.

It will be seen from the foregoing account that ironstones occur at several different horizons in the Coal Measures of the South Wales Coalfield. They range from the Monmouthshire black-band lying above the highest known coal-seam to the courses which lie near the base of the Coal Measures, and in the top of the Millstone Grit. The correlation of those which have been worked in different parts of the field is open to doubt. The majority, so far as regarded their profitable extraction, were limited to certain areas of indefinite extent. Others were found to be of local development, but some may be persistent throughout. It is certain, however, that courses of mine-ground are numerous and associated with the lower coal-seams in all parts of the field, and further that the amount which has been extracted is trivial in comparison with the amount which may be assumed to exist.

Under these circumstances it would be possible, in view of the great size of the field, to arrive at, and in a sense justify, an enormous estimate of reserves, but it is questionable whether any good purpose would be served by so doing. The estimate would bear little relation to the amount that could be worked under any circumstances at present conceivable. The available reserves would still remain a matter of pure speculation. It appears better therefore to adopt a figure, which though arbitrary is certainly not an overestimate, than to give one which would be of no account for practical purposes.

For this reason a round figure of 5,000 million tons upwards has been adopted as an estimate of reserves of Coal Measure iron-ores in South Wales and Monmouthshire.

The analyses which appeared in the 'Iron Ores of Great Britain,' *Mem. Geol. Survey*, part iii, 1861, are set out in the following table. Those of the Spotted Vein Mine, Three Quarter Balls, Black Pins (Blaenavon), Meadow Vein Mine, Three Cakes, Black Band,, Sulphury Mine and White Pins, were made by Mr. A. Dick. The analyses of the Spotted Vein Mine, Black Pin (Pontypool), Rosser Vein, Little Blue Vein, Lumpy Vein, Spotted Vein, Gwr-hyd Mine and Black Band (Dowlais) were made by Mr. E. Riley. The Black Band of Abercarn, the Catshole and the Kilvelgy ironstones were analysed by Mr. W. Ratcliffe. The ores from Cwm Celyn and Blaina were analysed by Dr. Noad. For further details of the methods of analysis, etc., reference should be made to the original account.

—	Blaenavon.			Pontypool.					Abercarn.	Cwm Celyn and Blaina.								Dowlais.						Cwmavon.	Ystalyfera.	Saundersfoot.	
	Spotted Vein Mine.*	Three Quarter Balls.*	Black Pins.*	Spotted Vein Mine (Balls).*	Meadow Vein Mine.*	Three Cakes Meadow Vein Mine.*	Black Pin Mine.* (Middle Pin).	Black Band.*	Black Band.	Red Vein.	Black Vein.	'Jack' in Red Vein.	Grey Vein.	Black Pin.	Red Pin.	Yellow Pin.	Top Soap Vein.	Bottom Soap Vein.	Rosser Vein Mine.	Little Blue Vein.	Lumpy Vein.	Spotted Vein.	Cwr-hyd Mine.	Black Band.	Sulphury Mine.*	White Pins.*	Catshole Ironstone.	Kilvelgy Ironstone.
Loss by roasting, per cent.	—	—	—	—	—	—	—	—	—	24·0	30·7	30·4	28·0	28·0	26·8	22·7	25·2	29·9	—	—	—	—	—	—	—	—	—	—
Protoxide of iron	45·22	36·10	41·22	44·50	32·44	26·03	26·98	31·74	3·37	—	—	—	—	71·70	57·99	48·30	59·61	77·34	41·03	38·47	44·29	—	39·00	48·66	40·30	29·34	33·088	34·274
Carbonate of iron	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sesquioxide of iron ...	—	—	—	—	—	—	—	—	4·10	73·79	80·22	51·12	70·50	—	—	—	—	—	0·41	0·40	0·41	76·61	—	—	—	—	0·637	3·366
Protoxide of manganese ...	1·05	0·76	1·07	0·73	0·80	1·09	0·49	1·06	1·50	0·92	1·02	not det.	not det.	1·42	0·64	0·327	—	0·53	0·55	1·30	1·13	1·21	0·50	1·21	1·03	0·73	1·213	1·467
Alumina	0·58	0·48	0·59	1·35	0·24	0·37	1·19	7·75	6·05	5·65	5·60	7·37	6·00	5·15	8·52	16·40	7·85	6·96	5·79	3·28	4·20	5·79	25·33	1·21	1·43	0·96	0·909	—
Silica	—	—	—	0·22	—	0·24	0·50	16·97	2·80	8·31	4·60	8·13	15·24	12·00	15·40	25·20	20·00	9·54	13·35	13·55	7·91	8·38	—	—	—	—	0·668	0·051
Lime	1·63	1·07	2·89	1·91	3·66	8·14	3·11	3·84	3·00	—	—	—	—	—	—	—	—	—	3·00	4·54	3·18	3·13	2·75	1·69	1·44	0·84	3·014	1·899
Carbonate of lime	—	—	—	—	—	—	—	—	—	2·95	4·65	19·80	1·98	2·64	3·45	1·20	4·50	none.	—	—	—	—	—	—	—	—	—	—
Magnesia	3·04	4·52	3·38	2·47	3·69	5·48	4·13	3·51	0·25	—	—	—	—	—	—	—	—	—	3·36	4·40	3·92	3·96	2·41	2·61	2·77	5·63	0·944	3·003
Carbonate of magnesia ...	—	—	—	—	—	—	—	—	—	3·80	2·91	11·88	3·90	4·23	8·58	6·00	4·80	0·90	—	—	—	—	—	—	—	—	—	—
Carbonic acid	31·58	27·33	30·07	30·92	26·15	28·29	23·40	25·03	30·50	—	—	—	—	—	—	—	—	—	28·49	30·53	32·48	—	26·14	33·09	28·23	24·56	22·283	26·141
Phosphoric acid	0·38	0·18	0·76	0·23	0·28	0·17	0·35	0·35	trace.	0·53	0·427		0·217	0·482	0·75	0·214	0·424	0·576	0·70	0·46	0·42	0·57	1·28	0·58	0·88	0·14	0·441	0·226
Sulphuric acid	trace.	trace.	trace.	—	trace.	trace.	—	trace.	1·56	trace.	trace.		trace.	trace.	trace.	trace.	trace.	trace.	—	—	—	—	—	—	—	trace.	0·597	0·149
Bisulphide of iron ...	0·71	0·11	0·15	0·11	0·30	0·69	0·52	0·48	—	0·17	0·123		0·119	trace.	0·241	0·124	0·246	0·192	—	—	—	—	—	0·07	0·09	0·08	0·446	0·287
Sulphur	—	—	—	—	—	—	—	—	—	—	—	not	—	—	—	—	—	—	—	0·01	0·03	0·06	—	—	—	—	—	—
Potash	—	—	—	—	—	—	—	1·12	0·32	0·48		det.		0·489	0·45	3·89	0·444	0·530	0·86	0·87	0·74	0·87	—	—	—	—	0·115	0·027
Water, hygroscopic ...	0·66	1·06	1·21	—	0·98	0·99	—	not det.	0·27	2·36	not det.		not det.	1·645	2·34	1·320	1·442	2·240	0·57	0·35	0·42	—	0·79	0·25	0·74	1·00	0·374	0·902
Water, combined				0·76	—	—	0·78		0·31										1·36	1·08	1·03	—	1·60	11·08			1·193	1·230
Organic matter	0·64	0·79	0·82	0·21	1·15	0·41	0·82	abt. 8·50	6·25										0·07	0·29	0·35	—	—	—	0·29	0·33	0·601	0·594
Insoluble residue	14·50	27·58	17·27	15·73	30·01	27·35	36·51	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	22·48	35·73	33·409	27·287
	99·99	99·98	99·43	99·14	99·70	99·25	98·78	100·35	100·28	98·96	99·55	98·30	97·956	99·756	98·361	99·474	99·316	98·802	99·54	99·53	100.51	100·58	99·80	100·45	99·68	99·34	99·932	100·903
Total iron	35·48	28·55	32·44	34·96	26·01	20·95	21·49	24·90	36·49	35·62	38·75	24·65	34·00	34·60	28·00	23·3	28·75	37·3	32·18	30·43	34·72	53·6 calcined	30·33	37·8	31·63	23·22	26·389	29·148

* Ore dried at 100° C.

RESERVES IN SOUTH WALES AND MONMOUTHSHIRE.

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